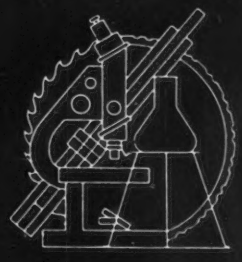
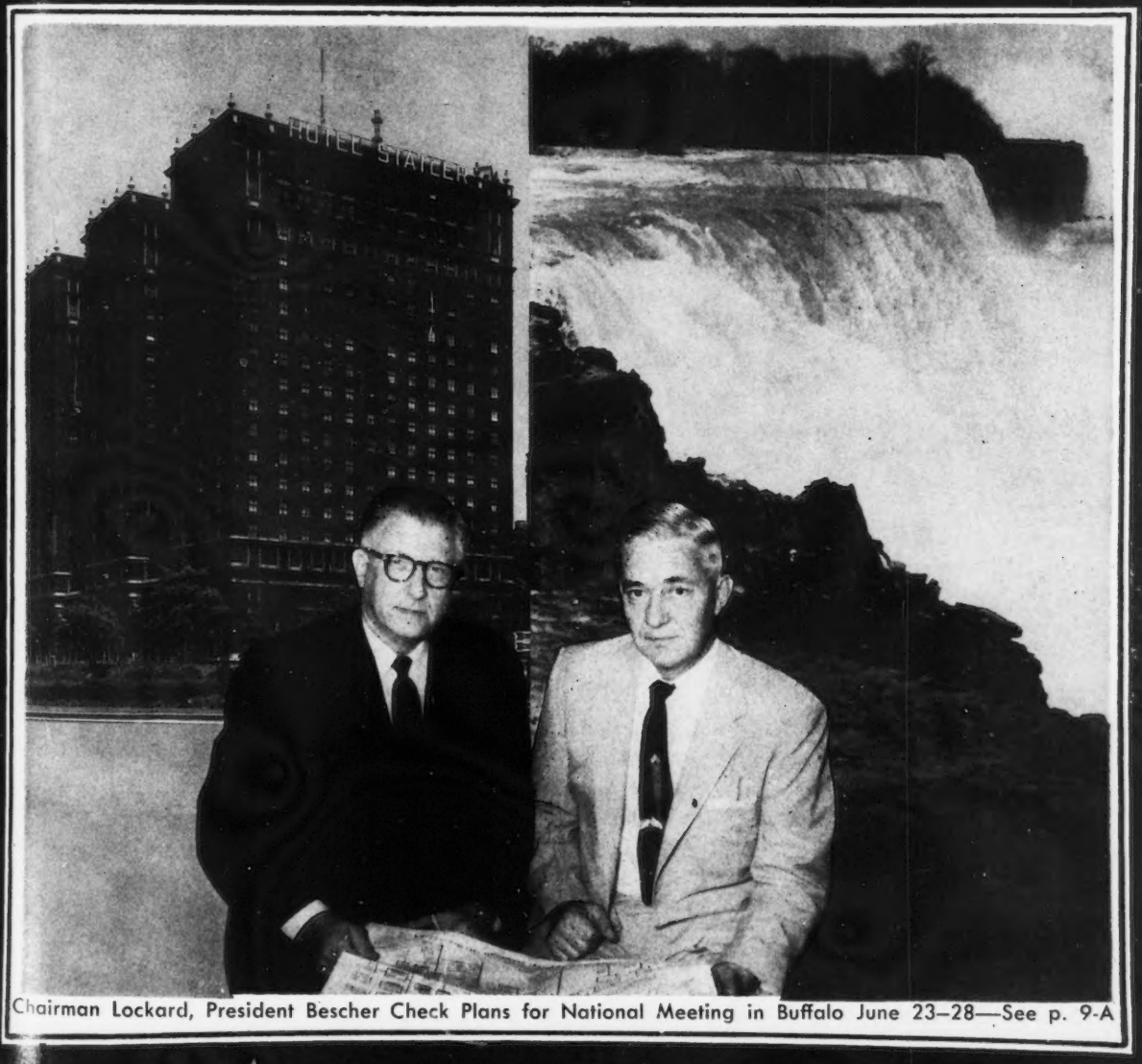
SANDING PARTICLE BOARD TO THICKNESS—p. 121

Forest Products Journal





Chairman Lockard, President Bescher Check Plans for National Meeting in Buffalo June 23–28—See p. 9-A

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CYANAMID

RESIN ADHESIVES

Want a slice of the particle board market?

Conservative estimates predict particle board consumption will mushroom from 1955's 70 million square feet to 600 million by 1960. Potential end uses are legion—walls, sliding doors, ceilings, subflooring, concrete forms, cabinets, signs, patterns, displays, furniture cores, underlayment for decorative laminates, to name only a few.

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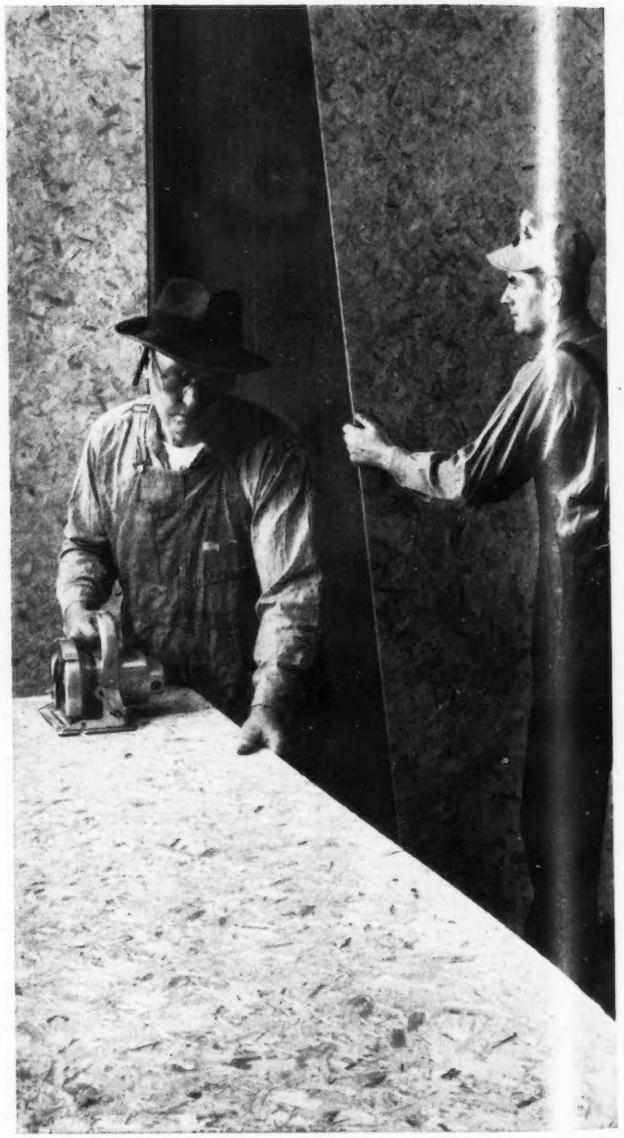
MELURAC 304, developed expressly as a particle board binder resin, offers you many advantages:

Easy handling, faster processing: MELURAC 304, a melamine-urea-formaldehyde resin, is a white, finely divided, free-flowing powder that may be blended dry or sprayed from water dispersion into wood aggregates. You can use 15° to 25°F lower cure temperatures or speed the the cure cycle 10 to 15% and in either case get less "blowing," blistering and sticking to cauls. The process lends itself well to automation.

Better properties with economy: MELURAC 304 produces maximum flexural strength and high moisture and water resistance. It imparts no color to the board, an advance in such binding resins that opens up many applications where the board forms an exposed surface. Easy working properties in some cases surpass those of wood; minimum splintering and breakage permit exposed edges to be finished readily.

With a MELURAC Resin 304 content of 3 to 7%, you can make better particle board at a cost competitive with ordinary resins. Here is a way to profit through fuller use of lumber resources. Write today for technical data and samples.



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FOREST PRODUCTS JOURNAL

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IMPORTANT FPRS DATES

May 9–10: Carolinas–Chesapeake Section Meeting, Clemson, S. C.

May 9–10: Midwest Section Meeting, Peoria, Ill.

May 13–14: Pacific Northwest Section Meeting, Roseburg, Ore.

May 31: Florida–Georgia–Alabama Section Meeting, Talladega, Ala.

June 24–28: Eleventh National Meeting, Hotel Statler, Buffalo, N. Y.

August: Upper Mississippi Valley Section Meeting, International Falls, Minn.

Oct. 21–22: Mid-South Section Meeting, Crossett, Ark.

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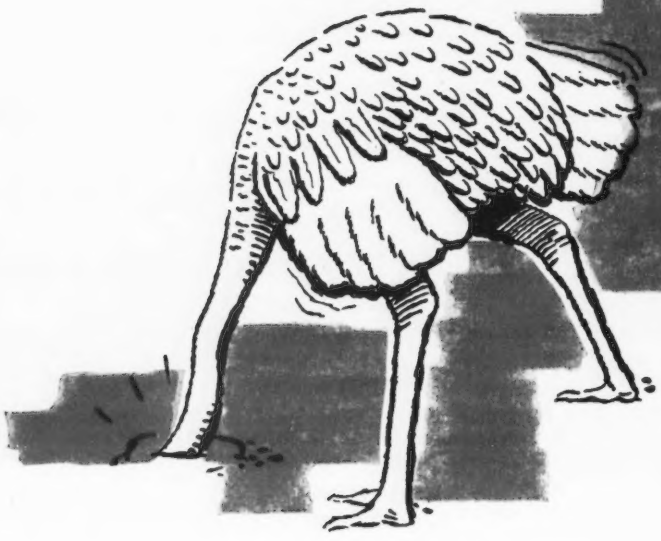

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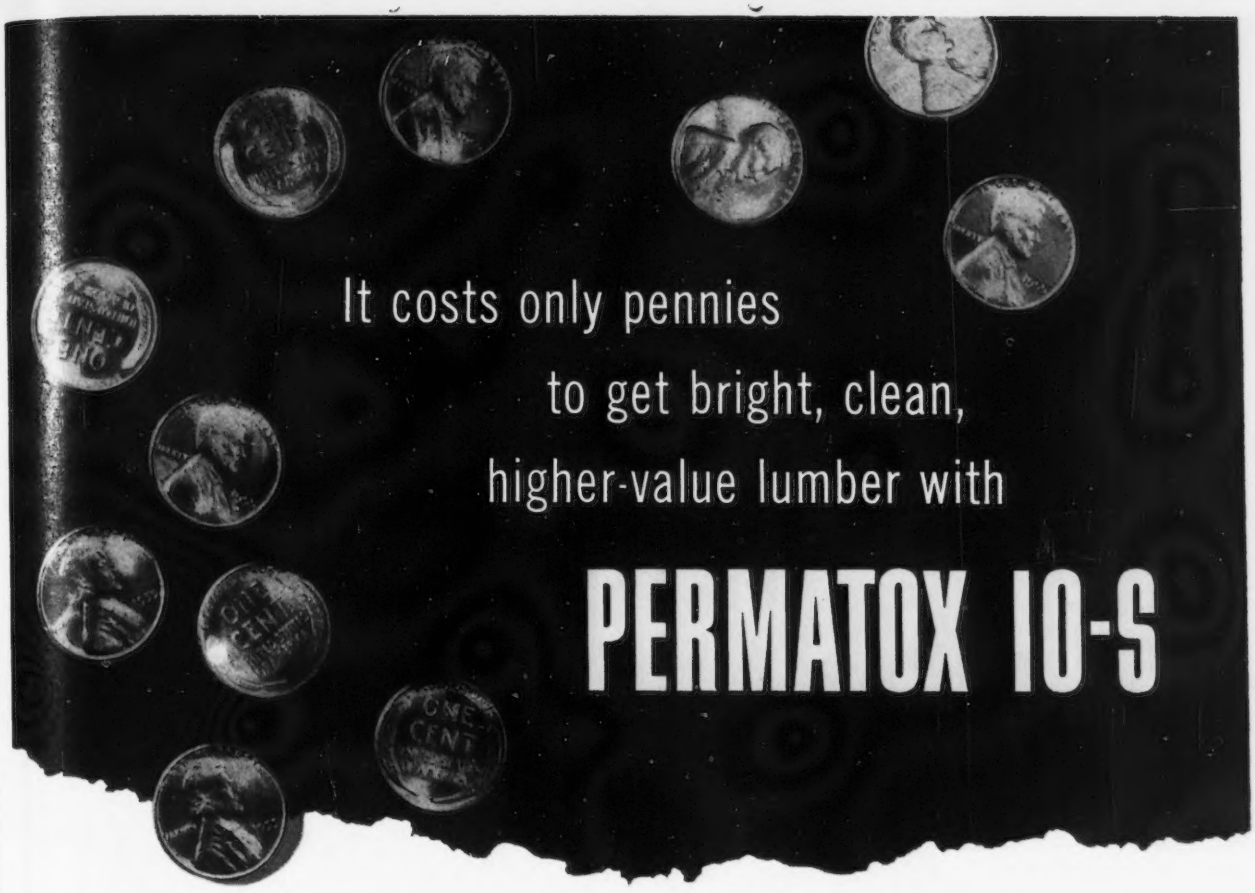

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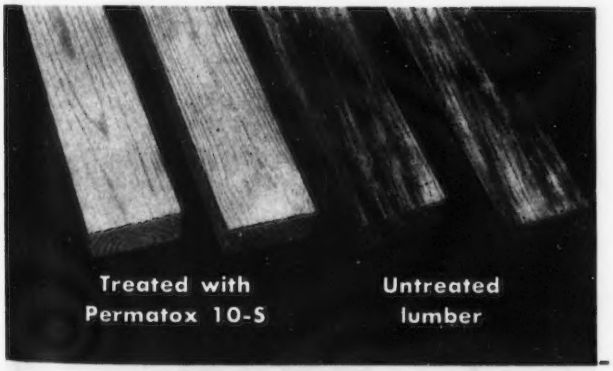

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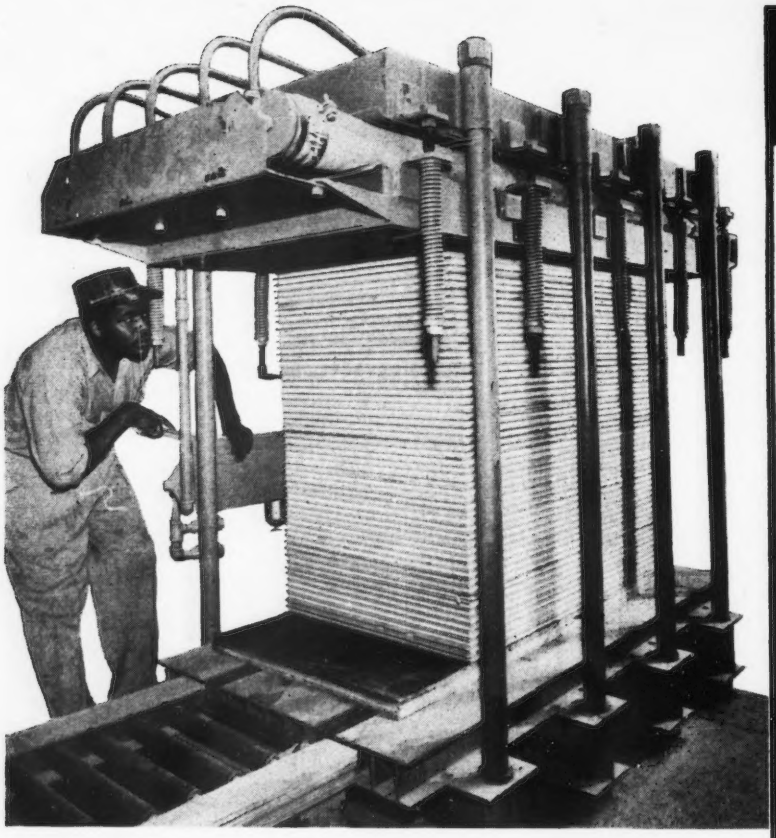

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We've taken your production problems . . . and designed machines to answer those problems. In hundreds of progressive plants throughout the world, the four presses shown here are the basis for modern production techniques in moderate pressure bonding operations. Perhaps one of these job-engineered presses will answer your laminating problem. The specific product bulletins will give you more detailed information. Write for them today!

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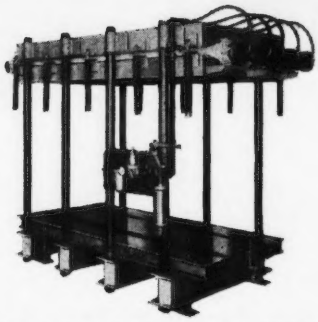
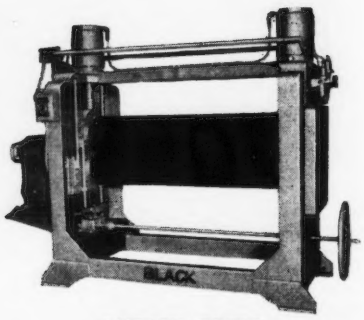


AIR HOSE LAMINATING PRESS



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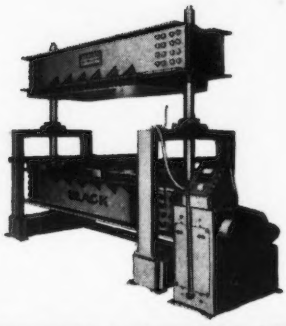
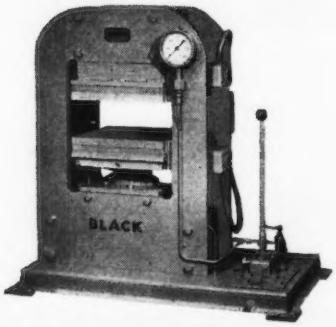


MOTORIZED LAMINATING PRESS



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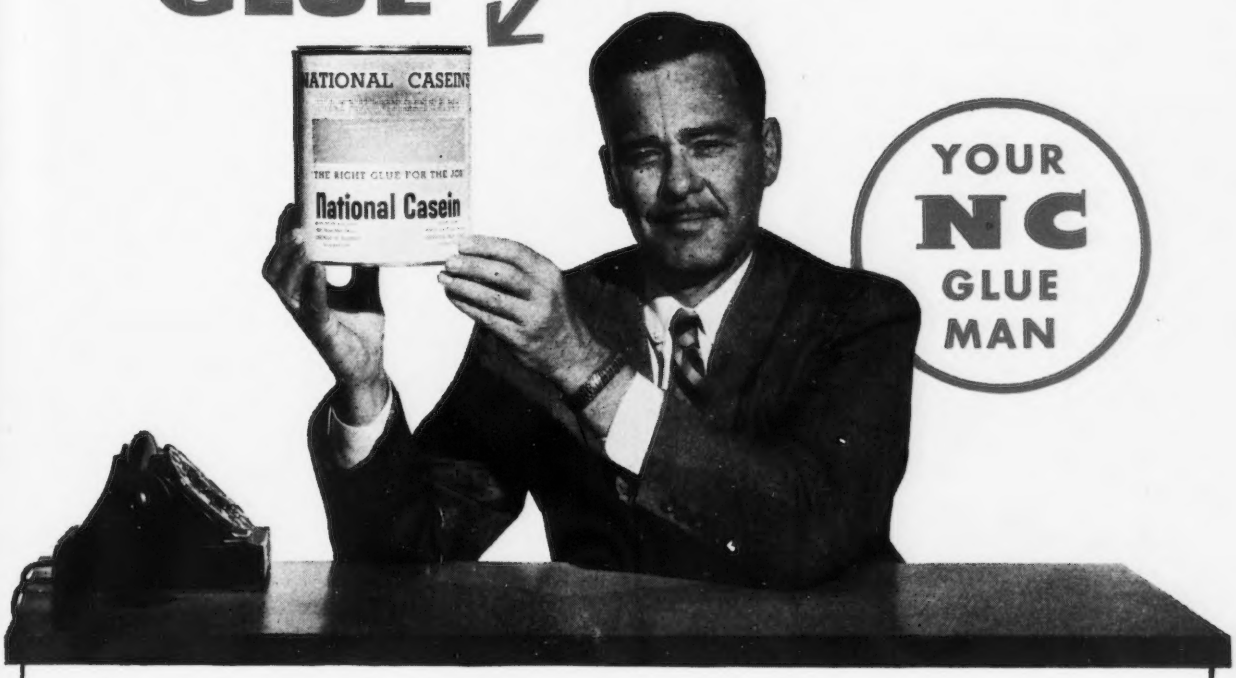

If you are one of the scores of users, you'll agree that National Casein's No. 5005 woodworking glue invites more superlatives than practically any other adhesive on the market.

Here's a quick-setting, freeze-resistant, liquid resin joint glue that comes to you all ready to use . . . *no mixing required.* There's no hardening in the glue pot—hence no waste from left-over glue.

National Casein's No. 5005 is a room temperature glue that is easily stored. No chilled joints.

You apply National Casein's No. 5005 by any convenient method—brush, roller-spreader, dip tank or spray gun.

Thirty minutes pressure is generally sufficient for a tough, durable joint with most woods. Easy on knives.

If you aren't using National Casein's No. 5005, now's the time to see what it can do for you.

National Casein

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Other Monsanto Adhesives include:

LAUXITE MF-300 *A melamine adhesive for colorless waterproof bonds.*

LAUXITE MF-325 *A specially formulated powdered melamine resin binder for granulated wood molding.*

RESINOX *Phenolic resins, liquids, and compounds, for granulated wood molding and hardboard.*

LAUXEIN *Versatile protein adhesives with specific formulations to meet varied bond requirements.*

LAUXITE UREA *Resin glues, both liquid and powder, for high water resistant bonds.*

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Monsanto supplies a complete line of Urea, Resorcinol, Melamine, Phenolic and Protein adhesives for the woodworking industry.

Announcing

FILER & STOWELL'S

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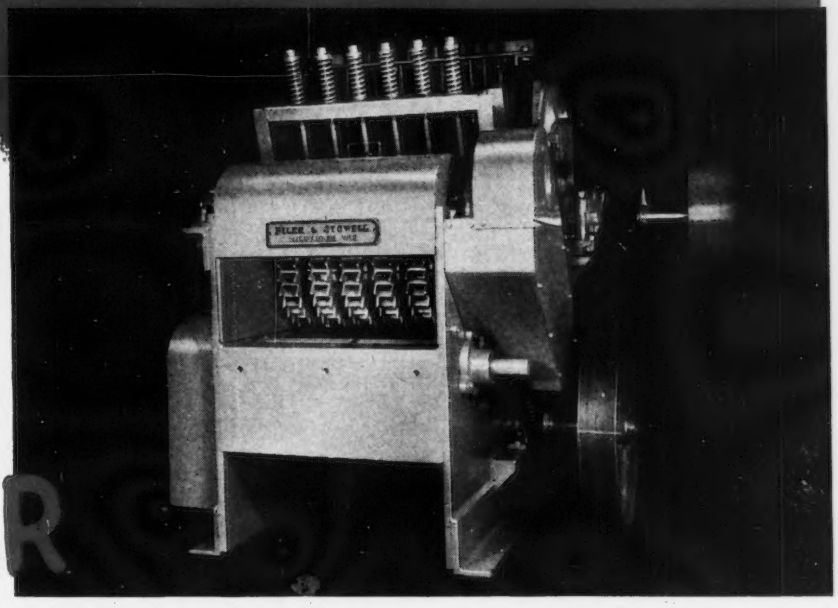
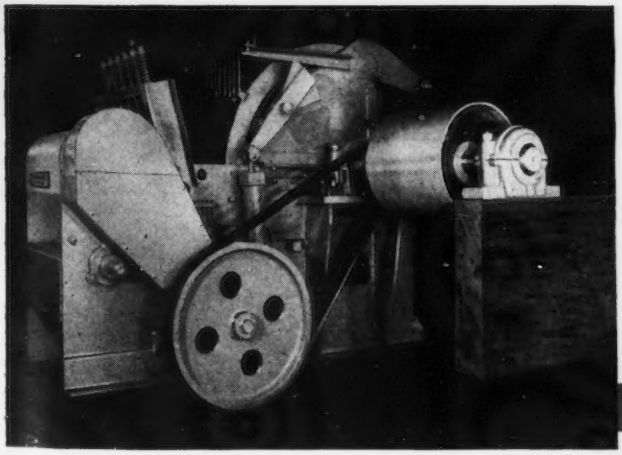


DESIGNED ESPECIALLY for SLABS, EDGINGS and TRIM BLOCKS



Converts sawmill waste to high-grade, uniform size pulp chips at the rate of 10 cords per hour! Contains features that sawmill operators have long wanted, such as: *Large opening designed for refuse; Simple installation; Controlled horizontal feed; Automatic clearing cylinder; Individually hung pressure fingers which follow contour of the knives holding the ends of the stock being chipped.* Discharge is either through bottom or at rear as desired. Available in different sizes.

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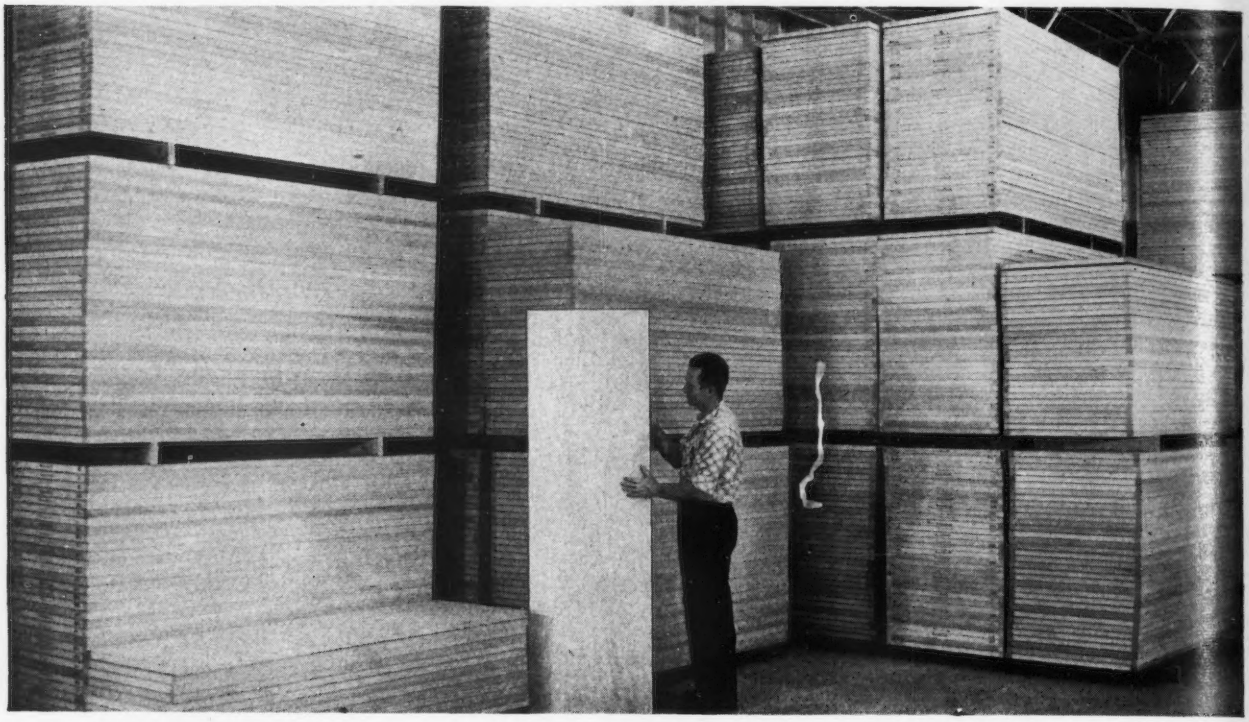

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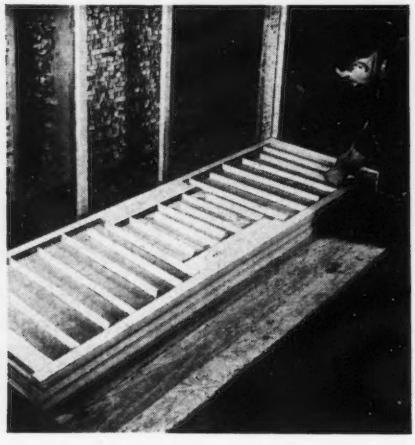
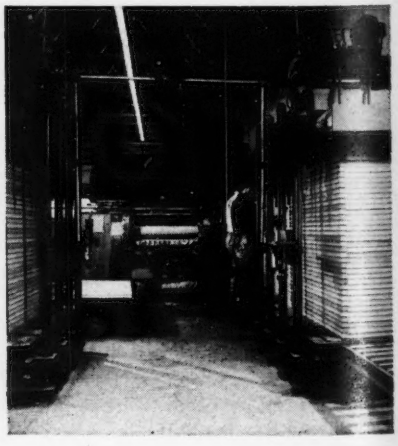
WOOD-LOK requires no mixing and is virtually odorless. It cleans up easily with water. All day pot life.

NO PRECURE
WOOD-LOK allows assembly time up to one hour without danger of precure. It's nonirritating to skin. Safe.

AIR HOSE PRESS
WOOD-LOK needs only a 20-30 min. press in Black Brothers' Air Hose Presses. Trim 2-3 hours later.





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FPRS NEWS-DIGEST

Volume VII APRIL, 1957 Number 4

View of downtown Buffalo, showing City Hall in center foreground. Hotel Statler is three-wing building at left.

Aerial view of majestic Niagara Falls, one of seven natural wonders of the world.

Variety of Scenic Attractions in Buffalo Area

Eleventh National Meeting Site Has Many Sightseeing Activities for Entire Family

A wide range of recreational, historical, and cultural activities awaits FPRS members, their families, and guests at the 11th National Meeting June 23–28 in Buffalo, N. Y.

FPRS headquarters in the Hotel Statler is a good base of operations from which to plan sightseeing, educational, and recreation trips. The 1,100-room hotel is centrally located on Niagara Square, convenient to all travel terminals as well as shopping and amusement centers. Most FPRS activities in the hotel will take place on the Mezzanine floor, the location of the Wood Industry and Suppliers Exhibit as well as principal meeting rooms.

Fabulous Niagara Falls

Meeting registrants and their families will be guests of industry suppliers at the Paul Bunyan Smorgasbord and evening tour of Niagara Falls. The Smorgasbord will be held on Wednesday evening, June 26, at Brocke Monument Park in Ontario, followed by a tour of the Falls. Considered to be one of the seven wonders of the world, the Falls take on added beauty at night, when 1,440,000 candlepower of light are reflected so that it penetrates the banks of heavy mist. Vari-colored screens are placed in front of the searchlights, causing the Falls to take on the appearance of a rainbow.

Those desiring further sightseeing at the Falls may want to return during the day, a 45-minute drive from FPRS headquarters. Some of the vantage points include Prospect Point, at the brink of the Falls; Cave of the Winds, carved out of the rock behind the Bridal Veil and American Falls; Terrapin Point, overlooking the brink of Horseshoe Falls; Three Sister Islands, affording view of the upper rapids; and Whirlpool State Park, from which one can view the whirlpool and lower rapids. Others may want to take the boat ride into the churning waters at the base of the falls.

Lobby of Hotel Statler, headquarters for FPRS Eleventh National Meeting.

Other Points of Interest

Fourteen miles north of the Falls lies historic Fort Niagara, one of the most strategic French posts in North America in the pre-Revolutionary War period. Built in 1725 and reconstructed in 1924, the fort contains the oldest masonry west of the Hudson River.

Points of historical interest in Buffalo include the site of President Millard Fillmore's home, the spot where President William McKinley was shot, and where President Theodore Roosevelt took the oath of office in 1901. North of the business district near the Niagara River channel is the site

(Continued on page 10-A)

Ballroom of Statler has seating capacity for banquets of 750 persons.

of the Battle of Black Rock in the War of 1812.

Also of interest to the sightseer is the Buffalo Museum which holds many scientific wonders, including the "transparent man" showing every nerve in the body. Children and adults will enjoy Delaware Park which houses the Buffalo Zoo. South of the city, near Lackawanna, N. Y., lie the famed Botanical Gardens.

Cultural points of interest include the Albright Art Gallery, Historical Museum, and Horticultural Building, all within a few minutes' drive from the Hotel Statler. Scene of operas, lectures, and other cultural events is Kleinhans Music Hall, noted for its acoustical and lighting features. Buffalo is also the home of four institutions of higher learning: Canisius College, D'Youville College, New York State Teachers College, and the University of Buffalo.

Recreational Features

A few miles from the Peace Bridge from Buffalo to Fort Erie, Ontario, lies Crystal Beach. In addition to the clean, sandy beach, rides for children and grown-ups and a dance pavilion are offered. Those seeking recreation may want to visit Hyde Park, 316 acres which include an 18-hole golf course, facilities for tennis, bowling, quoits, horseshoes, baseball, archery, cricket, soccer, skating, and a wading pool and playground for children.

For sports enthusiasts, harness racing is available at the Erie County fairgrounds at Hamburg, N. Y., a half-hour ride from Buffalo. Midget and stock car racing fans can enjoy these events in the Civic Stadium, a ten-minute drive from FPRS headquarters. Baseball fans may follow the fortunes of the Buffalo team at Offermann Stadium. The top farm team of the Detroit Tigers, Buffalo competes in the Class AAA International League.

Historic Fort Niagara is among outstanding tourist attractions in Buffalo area.

Composition Board Panel Invites Questions in Advance

What's your question on particle board? A panel of experts on particle board invites you to submit your questions now to be answered at the Wood Composition Board Session at the FPRS Eleventh National Meeting June 24–28 in Buffalo.

All questions—provocative, controversial, or otherwise—in the field of manufacturing, equipment, marketing, application, or research should be sent to Dr. George G. Marra, Division of Industrial Research, Washington State College, Pullman, Wash.

The goal of the session will be to find the best possible answers to the most puzzling questions of the day regarding particle board. The questions will be classified and submitted to panel members in advance so that discussion during the session can be channelled toward specific objectives, with audience participation also invited

"Quiz Master" J. R. Roberts, Weyerhaeuser Timber Co., will moderate the discussion, giving background information adequate to clarify the question before naming the respondents. Other panel members will then be asked for their views and the discussion opened to audience participation.

The following have been invited to represent various fields on the panel: adhesives, J. R. Ash, Monsanto Chemical Co.; research, A. L. Mottet, International Paper Co.; extrusion, C. E. Beech, Broyhill Furniture Co.; marketing, George Fisher, U. S. Plywood Corp.; utilization, William Drees, Formica Co.; and multi-platen, H. C. L. Miller, Miller-Hofft Co.

Typical examples of questions to be answered include: How high should bending strenth of particle board be for use as core in a furniture part? Does extruded board have as high screw-holding power as flat-pressed board? Are there any specifiable limits to density variation in a particle board which can be related to warping tendencies of finished products? What is the relationship between moisture content of the mat and press cycles? What is the research approach to the problem of thickness swell and linear expansion in particle boards? What is the optimum panel size for marketing particle board?

Two papers will also be presented as part of the session, with David McCalla, Fiberesin Plastics Co., serving as moderator. Wayne C. Lewis, U. S. Forest Products Lab, will discuss Particle Board and the Geneva Conference, and E. M. Williston, Weyerhaeuser Timber Co., will give an Analysis of the Panel Products Field.

ADVANCE REGISTRATION

ELEVENTH ANNUAL MEETING—FOREST PRODUCTS RESEARCH SOCIETY
BUFFALO, NEW YORK—JUNE 24–28, 1957

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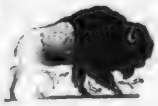


Program Covers Wide Range of Interests

More Than 50 Papers and Panels Scheduled on All Areas of Wood Research

"Something for everyone" is provided in papers and panel discussions to be presented at the FPRS Eleventh National Meeting June 23–28 in Buffalo. More than 50 papers are scheduled in the 12 technical sessions, according to Dr. F. H. Kaufert, program chairman.

A portion of the program is being geared to interests of the furniture industry, since many U. S. and Canadian furniture manufacturing centers are located near Buffalo. All areas of wood research will be covered thoroughly so that something of interest will be provided each day, as well as an opportunity to pursue any special interests.

The business portion of the program will officially begin with the General Opening Session on Monday afternoon, June 24. President Ralph H. Bescher will address the registrants and a major talk will be given by Dr. Lincoln Thiesmeyer, President of the Pulp and Paper Institute of Canada.

The technical sessions will follow the proved pattern of presentation of new material, followed by valuable floor discussion. The following schedule shows the tentative line-up of papers to date.

Session I—Glues and Gluing

9:00 a.m. Tuesday, June 25. Chairman: Alan A. Marra, University of Michigan, Ann Arbor, Mich. Vice-Chairman: R. F. Blomquist, U.S. Forest Products Lab, Madison, Wis.

"Dielectric Properties of Resin Glues for Wood"—T. J. S. Cole and D. G. Miller, Forest Products Laboratories of Canada, Ottawa, Ont.

"End Gluing of Lumber"—D. B. Richards, Alabama Polytechnic Institute, Auburn, Ala.

"New Developments in Wood Gluing Processes"—Panel Discussion

Session II—Wood Machining

9:00 a.m. Tuesday, June 25. Chairman: L. A. Patronsky. Vice-Chairman: Norman C. Bye, Disston Div., H. K. Porter Co., Philadelphia, Pa.

"Carbide Tool Technology"—Ted C. Weill, Carboloy Dept., General Electric Co., Detroit, Mich.

"Modern Methods for Modern Woodworking" — Clifford Baker, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

(Title to be announced)—Norman C. Franz, University of Michigan, Ann Arbor, Mich.

"Machining of Particle Board"—E. M. Davis, U. S. Forest Products Lab, Madison, Wis.

"Wide Belt Sanding"—Panel Discussion. Moderator: P. F. DeSaix, Carborundum Co., High Point, N. C.

Session III—Veneer and Plywood

2:45 p.m. Tuesday, June 25. Chairman: H. O. Fleischer, U. S. Forest Products Lab, Madison, Wis. Vice-Chairman: John Butler, Hardwood Plywood Institute, Atlanta, Ga.

"Plywood Imports and Their Effect upon U. S. Plywood Producers"—Harry Fidler, Owens-Illinois Plywood Co., North Troy, Vt.

"Development of a Highly Accelerated Test for Water-Resistant Hardwood Plywood"—C. A. Hart, N. C. State College, Raleigh, N. C.

"New Plywood Manufacturing Equipment"—E. D. Cottrell, Setter Bros., Inc., Cattaraugus, N. Y.

Session IV—Wood Finishing

2:45 p.m. Tuesday, June 25. Chairman: F. H. Thomas, Sherwin-Williams Co., Chicago, Ill. Vice-Chairman: D. G. Lubeck, Hammond Organ Co., Chicago, Ill.

"New Aspects in Paint Blistering"—D. F. Laughnan, U. S. Forest Products Laboratory, Madison, Wis.

"Blister and Stain Resistant Paints"—W. G. Vannoy, E. I. duPont de Nemours & Co., Wilmington, Del.

"Natural Exterior Wood Finishes"—Golden Gate Paint and Varnish Production Club, Neil Estrada, Reichhold Chemicals, Inc., South San Francisco, Calif.

"Wood Fillers"—P. A. Blachman, Glidden Co., Reading, Pa.

"Color Control in Furniture Finishing"—W. E. Martin, Grand Rapids Varnish Corp., Grand Rapids, Mich.

Session V—Logging

9:30 a.m. Wednesday, June 26 Chairman: F. C. Simmons, Northeastern Forest Experiment Station, Upper Darby, Pa. Vice-Chairman: Paul M. Dunn, St. Regis Paper Co., New York, N. Y. Moderator: W. R. Warner, Southern Lumber Co., Warren, Ark.

"Attaining Greater Logging Safety"—E. H. Reeves, Ontario Lumbermen's Safety Assoc., Toronto, Ont.

"Developments Leading Toward a Better Power Chain Saw"—James Conroy, Chain Saw Age, Portland, Ore.

"Harvesting Hardwood Logging Residues"—Leland Hooker, Michigan College of Mining and Technology, Houghton, Mich.

"Yarding with Rubber-Tired Wheel Skidders"—D. W. Gray, K. V. P. Co., Ltd., Espanola, Ont.

"Integrated Hardwood Logging"—J. C. Noblet, Calumet & Hecla Co., Calumet, Mich.

Session VI—Wood Composition Board

9:30 a.m. Wednesday, June 26. Chairman: George G. Marra, Washington State Institute of Technology, Pullman, Wash. Vice-Chairman: J. R. Roberts, Weyerhaeuser Timber Co., Longview, Wash. Moderator: David McCalla, Fiberesin Plastics, Inc., Oconomowoc, Wis.

"Particle Board and the Geneva Conference"—Wayne C. Lewis, U. S. Forest Products Lab, Madison, Wis.

"An Analysis of the Panel Products Field"—E. M. Williston, Weyerhaeuser Timber Co., Longview, Wash.

"New Developments in Particle Board"—Panel Discussion. Panel includes: J. R. Roberts, Moderator; J. R. Ash, Monsanto Chemical Co., Seattle, Wash.; A. L. Mottet, Long–Bell Division, International Paper Co., Longview, Wash.; C. E. Beech, Broyhill Furniture Co., Lenoir, N. C.; George Fisher, U. S. Plywood Corp., New York, N. Y.; William Drees, Formica Co., Cincinnati, Ohio; and H. C. L. Miller, Miller–Hofft, Inc., Richmond, Va.

Session VII—Wood Preservation

9:30 a.m. Wednesday, June 26. Chairman: Ira Hatfield, Wood Treating Chemicals Co., St. Louis, Mo. Vice-Chairman: C. S. Walters, University of Illinois, Urbana, Ill.

"Effects of Soil, Moisture, and Aeration Variables on Bioassay by the Soil Block Culture Method"—S. S. Sakornbut and R. J. Balske, Monsanto Chemical Co., St. Louis, Mo.

"Factors Affecting the Soaking Treatment of Basswood at Low Temperatures"—C. S. Walters.

"How to Build Better Frame Homes"—C. Miles Burpee, American Wood Preservers Institute, Chicago, Ill.

"Pentachlorophenol and Heavy Petroleum for the Preservative Treatment of Railway Cross-Ties"—G. E. Olson, F. J. Meyer, and R. M. Gooch, Dow Chemical Co., Midland, Mich.

"Commercial Use of Double Diffusion as a Wood Preservation

Method"—A. S. Macdonald, Everdure, Inc., Orange, Va.

Session VIII—Chemical Utilization (Lignin)

9:00 a.m. Thursday, June 27. Chairman: E. G. Locke, U. S. Forest Products Lab, Madison, Wis. Vice-Chairman: A. S. Gregory, Weyerhaeuser Timber Co., Longview, Wash. Moderator: Walter F. Holzer, Crown Zellerbach Corp., San Francisco, Calif.

"Chemical Utilization of Lignin"—I. A. Pearl, Institute of Paper Chemistry, Appleton, Wis.

"Separation and Properties of Hemicellulose, Cellulose and Hydrogenated Lignin from Sawdust"—Conrad M. Schuerch, State University of New York College of Forestry, Syracuse, N. Y.

"The Lignin Dimethyl Sulfide Process"—W. M. Hearon, Crown Zellerbach Corp., Camas, Wash.

"Activated Carbon from Spent Pulp Liquor"—J. W. Hassler, West Virginia Pulp and Paper Co., Tyrone, Pa.

"Evaluation of Efficiency and Effects on Utilization by Various Methods for Removing Sugars from Lignosulfonates of Spent Sulphite Liquor"—G. A. Dubey, L. A. Boggs, Philip Luner, and A. J. Wiley, Sulphite Pulp Manufacturers' Research League, Appleton, Wis.

Session IX—Wood Drying

9:00 a.m. Thursday, June 27. Chairman: L. D. Espenas, Oregon Forest Products Laboratory, Corvallis, Ore. Vice-Chairman: S. B. Preston, University of Michigan, Ann Arbor, Mich.

"Mechanical Properties of Red Oak Related to Drying"

"Kiln Drying of Southern Hardwood Cross-Ties"—J. B. Huffman, University of Florida, Gainesville, Fla.

"Variation in Moisture Content of Air-Seasoned Southern Pine Lumber"—R. M. Carter, N. C. State College, Raleigh, N. C.; and Rufus H. Page, Forest Utilization Service, U.S.F.S., Macon, Ga.

"Factors Affecting the Cost of Hardwood Drying"—Edwin Conway, Lumber Drying Specialties, Grand Rapids, Mich.

"Stacking, Stickers, and Related Problems"—Panel Discussion. Panel includes: Ray C. Rietz, Moderator, U. S. Forest Products Lab, Madison, Wis.; Hereford Garland, Michigan College of Mining and Technology, Houghton, Mich.; Frank Cook, Moore Dry Kiln Co., Portland, Ore.; Percy Deverick, Kent Coffee Manufacturing Corp., Lenoir, N. C.

Session X—Lumber Manufacturing

9:00 a.m. Thursday, June 27. Chairman: Milton H. Mater, Mater Machine Works, Corvallis, Ore.; Vice-Chairman: E. P. Ivory, Ivory Pine Co., Dinuba, Calif.

"Dimensional Quality Control in a Large Western Sawmill"—Charles M. Kreider and Marvin W. Coats, Brooks-Scanlon, Inc., Bend, Ore.

"Dimensional Quality Control in a North Central Hardwood and Softwood Sawmill"—D. N. MacRae, Connor Lumber & Land Co., Laona, Wis.

"Effect of Various Types of Equipment on Sawing Accuracy in Eastern Canadian Hardwoods and Softwoods"—G. Brodie Gillies, Gillies Bros. & Co., Ltd., Braeside, Ont.

"Can Lumber Compete?"—J. S. Bethel and A. C. Barefoot, Jr., N. C. State College, Raleigh, N. C.

"Power Requirements for Log Carriage Setworks"—Milton H. Mater, Mater Machine Works, Inc., Corvallis, Ore. (To be presented by title only)

Session XI—Chemical Utilization (General)

2:00 p.m. Thursday, June 27. Chairman: E. G. Locke, U. S. Forest Products Lab, Madison, Wis.; Vice-Chairman and Moderator: A. S. Gregory, Weyerhaeuser Timber Co., Longview, Wash.

"Recent Advancements in Pine Gum Chemistry"—E. L. Patton and J. C. Braun, Naval Stores Station, Southern Utilization Research Branch, U. S. Dept. of Agriculture, Olustee, Fla.

"Structure and Composition of Aspen Bark"—R. L. Hossfeld and F. H. Kaufert, School of Forestry, University of Minnesota, St. Paul, Minn.

"Extraneous Components of Western Red Cedar"—J. A. F. Gardner and G. M. Barton, Forest Products Laboratories of Canada, Vancouver.

"Chemical Properties, Derivatives and Uses of Levulinic Acid"—Carl Bordenca, Heyden Newport Chemical Corp., New York, N. Y.

"Charcoal Production in Kilns"—Edward Beglinger, U. S. Forest Products Lab, Madison, Wis.

Session XII—Quality Control

2:00 p.m. Thursday, June 27. Chairman: Charles Latimer, Nickey Bros., Memphis, Tenn. Vice-Chairman: R. C. Calahan, Singer Sewing Machine Co., Clydebank, Scotland

"Quality Control Pays Off in Woodwork"—Robert Chateauneuf, Singer Manufacturing Co., St. Johns, P. Q.

(Title to be announced)—Vince Ross, Draper Corp., Swannanoa, N. C.

(Title to be announced)—John Saunders, A. G. Spalding & Bros., Inc., Chicopee, Mass.

Koppers Co. President To Address FPRS Official Luncheon at Buffalo Meeting

FRED C. FOY

"The Challenge of Forest Prod cts Research" will be the topic of the alk to be presented by Fred C. Foy, p sident of Koppers Company, Inc., F tsburgh, Pa., at the Official FI RS Luncheon at the National Meetin in Buffalo, Tuesday June 25. Foy ill come before FPRS well-equipped or this challenging task with a b k-ground of more than 25 years' exp ri-ence in advertising and sales.

Foy joined Koppers Company in 1948 as vice-president and manage of its Central Staff Sales Department, directing development of sales poli ies and the coordination of the sales efforts of the six Koppers' operating divisions.

In 1950 he was elected vice-president and general manager of the Koppers' Tar Products Division. Four years later he was elected to the board of directors, and in 1955 was named to his present position as president.

A native of San Francisco, Foy was graduated from the University of California at Berkeley. After serving as manager of public relations for he San Joaquin Light and Power Cor o-ration at Fresno, Calif., he joined the J. Walter Thompson Company Advertising Agency in 1930. Three years later he became advertising manager of the Shell Oil Corporation, and l er joined the Young and Rubicam dvertising Agency.

After service in Washington dur g World War II as assistant direc r, than director, Purchases Divisi n, Army Service Forces, with the rank of Colonel, he again joined the J. Wa er Thompson Company as vice-presid nt and manager of its Detroit office. In this capacity he was in charge of he Ford Motor Company advertising ac-count.

Prominent in community work, Foy is a active member of several civic and business organizations in the Pittsburg area. Among his activities and affiliations are: assistant to the president and director of the Pittsburgh Chamber of Commerce; president, Civic Business Council; director, Community Chest of Pittsburgh; director, West Penn Hospital; and board member, National Industrial Conference Boa

F–G A Section Schedules Spri Meeting in Alabama

Demonstrations of practical applications of the economics of recovery of waste fibers obtained from portable mills slab concentration yards, and medium-sized sawmills will be featured at the spring meeting of the Florida–Georgia–Alabama Section May 31 at the Purefoy Hotel, Talladega, Ala. The program is being arranged by Gus Jacobson, Windell Vickery, and Louis Gaby.

The program will consist largely of visits to debarking, chipping and screening operations. The group will travel by chartered bus to installations at Anniston, Goodwater, Weogufka, Sylacauga, Childersburg, and Talladega. The following machines will be demonstrated in operation: Sumner Iron Works slab barker and Sumner 52-inch standard spout chipper, Hurricain barker, Hansel horizontal chipper, Link Belt screen, PM Cary-lift, Wheland–Henry gangsaw, Soderhamn D-4 barker, Soderhamn slab chipper and chip screen, Improved Machine Co. mechanical rotor barker, Soderhamn slab barker-chipper, Cambio debarker, and a special automatic pulpwood feeder.

Following a social hour at 6:00 and dinner at 7:00, there will be an open discussion of the field trip and of other matters of interest to members and guests. Soderhamn Machine Manufacturing Co. will be host at both the Friday lunch and the social hour. The registration fee of $5.00 covers the cost of the dinner and bus fare for the tours.

Carolinas–Chesapeake Section Plans Spring Meeting May 9–10

The program for the spring meeting of the Carolinas–Chesapeake Section to be held May 9–10 at the Clemson House, Clemson, S. C., has been announced by James S. Bethel, program chairman.

Topics to be covered during the meeting will include foam extension of urea resin adhesives, veneer drying, dimensional stability in dry formed particle boards, labor problems in the wood industry, and others. Meeting attendees will have an opportunity to visit the Poinsett Lumber and Manufacturing Co., Pickens, S. C., where they will observe mountain logging, flat-press particle board plant, veneer mill, band sawmill, and sewing machine cabinet plant.

Laboratory Tour Featured At Midwest Meeting May 9–10

A tour through the U. S. Department of Agriculture's Northern Utilization Research Branch Laboratory will be one of the highlights of the Spring Meeting of the Midwest Section May 9–10 in Peoria, Ill. Two staff members of the laboratory will address the group following the tour.

Development of new uses for principal farm residues and commodities is the objective of the Peoria laboratory. Research investigation and experimentation are carried on in chemistry and related sciences dealing with processing and utilization of agricultural commodities and by-products for foods, feeds, fibers, drugs, and industry.

In addition to the Laboratory tour, plant tours are also scheduled the following afternoon to Barrett Division, Allied Chemical and Dye Corp., manufacturers of roofing felt from local hardwoods; and Hiram Walker & Sons, Inc., one of the world's largest distilleries. In addition to the technical sessions, the meeting will also include a luncheon and a Paul Bunyan Hour.

Registration fee for the meeting is $6.50, which includes registration, Paul Bunyan Hour, Official Luncheon and plant trips' transportation. Members are invited to bring guests, who will receive a gift from the Midwest Section in the amount of $7.00 toward the $15.00 annual membership dues in FPRS and all of its attendant benefits. This offer is limited to the first 50 guests registering.

Upper Mississippi Section Announces August Meeting

Manufacture of particle board will be the theme of the next meeting of the Upper Mississippi Valley Section, tentatively scheduled to be held in August at International Falls, Minn., Chairman Henry Crandall has announced. The subject was selected because of the great interest in particle boards of both low and high density.

In addition to the formal meeting, plans are being made for a tour through the new particle board plant of the Minnesota and Ontario Paper Co. at International Falls. Tentative plans also include a visit to the company's woods operations. Section Treasurer Wayne Meek, research chemist at M. & O. Paper Co., was named Program Chairman for the meeting.

FPRS Salutes . . .

Men Contributing Time and Efforts for Furtherance of the Society and Wood Industry

A. G. BATTAGLIA

A. G. Battaglia Designated representative of National Starch Products, Inc., one of FPRS's newest Company Supporting Members, Mike pitched right in and lent his active support to Society affairs. Recently he assumed the chairmanship of the Paul Bunyan program at the National Meeting, replacing another enthusiastic FPRS leader, Joseph Coufal, now of Gray Products Co., Waverly, Va. Along with David Rosse, an associate at National Starch, Mike is arranging for firms to sponsor the traditional Paul Bunyan program. This will include a smorgasbord supper at Brocke Monument Park in Ontario and Niagara Falls tour on June 26. Mike is head of National's Structural Adhesives Department, where he supervises the development and marketing of adhesives. A graduate of Manhattan College with a B. S. degree in chemistry, Mike has had more than 10 years' experience in the technical end of the adhesives business.

G. B. FAHLSTROM

George B. Fahlstrom—FPRS meetings traditionally have been a combination of technical sessions and on-the-spot "how to" or product demonstrations at leading wood industry plants. Once again this idea will be followed at the National Meeting in Buffalo with a diverse plant tour program covering a wide range of wood products applications planned. George has arranged for FPRS registrants to visit four plants in the Buffalo area, and planned two special side trips. An "old hand" in Society activities, George joined FPRS in 1947. Formerly a wood technologist with the Casein Company of America, he is now director of research for the Osmose Wood Preserving Co., Buffalo.

D. K. SAUNDERS

Donald K. Saunders—Don is doing a double-barreled job at the Buffalo meeting. As financial chairman he's in charge of the dollars and cents operations, and as host section chairman he oversees national meeting arrangements at the section level. A member of FPRS for six years, he was named to the executive board of the Northeast Section in 1952. Don served as Vice-Chairman for two years, and now is Chairman of the Northeast Section. Don joined Saunders Brothers at Westbrook, Me., following graduation from Dartmouth in 1935. He became president of the firm in 1950.

Quotas Assigned for Building Fund-Raising Drive

Nation-Wide Committee Kicks Off Campaign for $60,000 Before National Meeting

R. H. BERRY

Detailed plans for the fund-raising drive for the proposed Executive Office Building in Madison, Wis., have been announced by Raymond H. Berry, Southwest Regional Board Member and Chairman of the Fund-raising Committee.

A nation-wide team has been named to assist in the drive to raise a total of $60,000 in cash and pledges by June 24, opening day of the Eleventh National Meeting. Regional board members will coordinate the drive in their regions, with Section officers and other leaders in FPRS activities working with them to give full geographical coverage.

Regional Quotas Set

Quotas to be raised in each region have been assigned on the basis of membership, with specially appointed committee members working on a state-by-state basis. The amounts sought in each region are: Northeast, $16,000; Southeast, $8,000; North–Central, $16,000; South–Central, $4,000; Northwest, $12,000; and Southwest, $6,000.

Initial appeal for funds was made earlier this year to individual members, with more than $2,000 subscribed to date. In the next phase of the drive, regional board members prepared lists of prospective donors in their areas. These consisted of foundations, philanthropic organizations, corporations, and individuals interested in the advancement of wood research who might contribute $100, $500, and $1,000 or more each.

Kick-off date for this part of the drive was April 15, with committee members receiving a list of prospective donors to contact. A special brochure was prepared for their use which outlined plans for the drive, the present need, estimated costs, and giving a description of the proposed building.

Between now and the National Meeting in Buffalo, committee members will also attend Section meetings to report on progress toward the goal and to enlist further financial support. Final results of the drive will be announced at the Buffalo meeting.

If the committee's goal of $60,000 is achieved, it is expected that construction will proceed so that the building may be dedicated during the Twelfth National Meeting in Madison, Wis., in June 1958.

Committee Named

Committee members assisting in the drive are:

Members at large: FPRS President Ralph H. Bescher, Koppers Co., Inc., Pittsburgh, Pa.; and Vice-President W. J. Eason, Nickey Brothers, Inc., Memphis, Tenn.

Northeast Region: Chairman, Charles R. Lockard, Northeastern Forest Experiment Station, Upper Darby, Pa.; Northeast Section: D. K. Saunders, Saunders Bros., Westbrook, Maine; Eastern Canadian Section: E. A. Thompson, Canada Creosoting Co., Montreal, Que.

North-Central Region: Chairman, Robert L. Hiller, American Cyanamid Co., Chicago, Ill.; Midwest Section: J. J. Allegretti, Masonite Corp., Chicago, Ill.; Ohio Valley Section: John H. Wilson, Wilson Brothers, Indianapolis, Ind; Upper Mississippi Valley Section: Henry Crandall, Mosinee Paper Mills Co., Mosinee, Wis.; FPRS President-Elect F. H. Kaufert, University of Minnesota, St. Paul, Minn.; Great Lakes Section: Gardner C. Garlick, Protection Products Manufacturing Co., Grand Rapids, Mich.

Northwest Region: Chairman, John D. Ritchie, Douglas Fir Plywood Association, Tacoma, Wash.; Pacific Northwest Section: R. W. Wellwood, University of British Columbia, Vancouver, B. C.; Inland Empire Section: H. B. McKean, Potlatch Forests, Inc., Lewiston, Idaho.

Southeast Region: Chairman, W. L. Irwin, Poinsett Lumber and Manufacturing Co., Pickens, S. C.; Carolinas-Chesapeake Section: J. B. Veach, Jr., Hardwood Corp. of America, Asheville, N. C.

South-Central Region: Chairman, W. R. Warner, Southern Lumber Co., Warren, Ark.; Arkansas: D. M. Fisher, Jr., Southern Lumber Co., Warren; Tennessee: J. M. Crafton, Clearcraft Corp., Morristown; Texas: J. L. Love, Love Wood Products, Diboll; Oklahoma: Al Pakula, Oklahoma A & M College, Stillwater; Louisiana: Moss B. Christian, Chicago Mill and Lumber Co., Tallulah; Mississippi: John Squires, Mississippi Products, Inc., Jackson.

Southwest Region: Chairman, R. H. Berry, Scott Lumber Co., Burney, Calif.; Rocky Mountains: T. W. Schomburg, Denver, Colo.; W. R. Fritze, Koppers Co., Denver; U. R. Armstrong, Hallock and Howard Lumber Co., Denver; Pacific Southwest Section: Paul Yankauskas, Sawyer Cabinet Co., Los Angeles; A. J. Long, Monsanto Chemical Co., Los Angeles; W. E. Ripley, Jr., Stauffer Chemical Co., Los Angeles; Northern California Section: Homer N. Stephenson, Sacramento Box and Lumber Co., Sacramento; R. R. Chaffee, Wolf Creek Timber Co., Berkeley; B. C. Manson, Simpson Redwood Co., Eureka, Calif.; Lee Moffett, Tarter, Webster & Johnson, Inc., Stockton, Calif.

Pacific Northwest Section Meets May 13–14 in Roseburg

Sawmilling and Plywood Manufacturing will be the theme of the spring Meeting of the Pacific Northwest Section May 13–14 in Roseburg, Oregon. P. L. Northcott, Section Secretary, has announced. Details of the program will be mailed to members of the Section in the near future, he added.

CONTRIBUTION OR PLEDGE CARD

Name _____

Address _____

I hereby (contribute) (pledge) my support to the proposed FPRS Executive Office Building to be erected as early as possible, consistent with conservative business practice, in Madison, Wisconsin.

(Check here for Contribution and enclose check or money order) ☐ $_____

(Check here for Pledge. We will invoice you for the amount of pledge during calendar year 1957) ☐ $_____

Signed _____

INDUSTRY NEWS

A. B Hood Elected President of W stern Pine Association

Pr pt salvage of fire and pest-strick government timber and the sale full allowable cut of government agency-managed forest lands were ged in actions by the Western Pine sociation at its annual meeting in S Francisco in March. A recent surve showed that 72 per cent of commer timberland in the association's 12-st region is government held.

It as announced at the meeting that HA has accepted the association's laboratory-developed sheathing panel Sheet-Board, which has been in prod tion for several months. In other actions, the board of directors appro ed an increased budget for the group s research activities and an increased promotional budget.

A. B. Hood, general manager of Ralph L. Smith Lumber Co., Anderson, Calif., was elected president. Other officers named included: J. D. Bronson, Cascade Lumber Co., Yakima, Wash., and P. V. Burke, Sacramento Box and Lumber Co., Sacramento, Calif., both vice-presidents; and C. T. Gray, American Forest Products Corp., San Francisco, treasurer.

Statistics Short Course Scheduled in North Carolina

The Institute of Statistics at North Carolina State College, Raleigh, will sponsor an intensive one-week short course in Statistics Methods for research workers in industry and the physical sciences June 3–7. The course will be held at Brevard College, Brevard, N. C.

The course will be run in two sections—elementary and advanced. The elementary section will cover basic concepts, confidence limits, tests of significance, correlation and curve fitting, analysis of variance, and an introduction to design of experiments. Among topics in the advanced section will be variance components, multiple regression, response surface methods, experimental design and analysis of organoleptic experiments.

A registration fee of $100 will be charged, with enrollment limited to 50 students in each section.

Plywood Safety Record

The world's record for industrial safety in the plywood industry goes to Algoma Plywood and Veneer Co., Algoma, Wis., subsidiary of U. S. Plywood Corp. The award for this record, prescribed by the National Safety Council, resulted from operation of the Algoma plant 1,551,002 hours during 1956 without a disabling injury.

Studies Completed on Use of Short Logs in Furniture

A research project to study the possibility of using short logs not suitable for the production of commercial grades of lumber to produce furniture stock has been completed. The project was sponsored by the Southern Furniture Manufacturers' Association in cooperation with North Carolina State College, Raleigh, N. C.

The results of the study have been published by the Association in a 100-page book, "Short Log Bolter for Furniture Stock," distributed to its members. The report was written by Asst. Prof. George P. Redman of N. C. State College under the supervision of Prof. Rudolph Willard of the School of Engineering at N. C. State College.

In this series of experiments conducted at the Wood Products Laboratory at N. C. State, tests were made using poplar, oak, and gum. The study shows that where short logs that are not suitable for the production of commercial grades of lumber are readily available to manufacturers of furniture, the use of a short log bolter saw can result in a new source of furniture stock at a saving to the manufacturer.

Penn State University Plans Fifty-Year Celebration

Fifty years of forestry education in Pennsylvania will be celebrated May 27 and 28 at Penn State University, University Park, Pa. The meeting commemorating the establishment in 1907 of a four-year forestry curriculum at Penn State is expected to attract nearly 600 foresters from all parts of the country. It is sponsored by the Penn State–Mont Alto Forestry Alumni Association.

Speakers at a banquet highlighting the two-day event will include Richard E. McArdle, chief of the U. S. Forest Service, Gov. George M. Leader, and Penn State President Eric A. Walker. A memorial to forestry alumni war casualties will be dedicated and a book, "Forestry Education in Pennsylvania," will be published in conjunction with the celebration.

Kiln Association Formed In Southern Illinois

Howard C. Tooke was elected president of the Egyptian Kiln Drying Association at the organizational meeting March 22 in Cairo, Ill. Tooke is president of M. E. Leming Co., Cape Girardeau, Mo. Other officers are: F. O. Groscurth, president of Ulrich-Groscurth Co., Cairo, Vice-President; and William W. Rice, coordinator of Industrial Wood Technology Dept., V.T.I., Southern Illinois University, Carbondale, Ill, Secretary-Treasurer.

Fifteen persons joined the association at the meeting, which consisted of a demonstration and discussion of various wood-moisture relationships by John Devine, Moore Dry Kiln Co., and a talk by Mr. Rice on wood cells and how they are affected by moisture. The members voted to meet twice a year in the spring and fall, and tentatively scheduled the next meeting in September at Cape Girardeau.

Membership in the association is open to all dry kiln operators, superintendents, managers, and other officials. Each member receives as part of his membership the monthly newsletter published by the FPRS Wood Drying Division.

Fischer Process Being Used in New Formaldehyde Plant

A new formaldehyde plant with an annual production capacity of 36 million pounds was opened at Kent, Wash. last month by the Borden Company's Chemical Division. The firm has a similar operation at Springfield, Ore., and now operates five West Coast chemical plants.

The Kent operation is the first to use Borden's Karl Fischer process, for which U. S. rights were leased from Apparate und Rohrleitungsban, West Germany. The process is said to permit a high yield in formaldehyde production and lower utility and steam requirements for processing.

Western Pine Mills Increase Kiln Capacity

Kiln drying capacity of Western Pine Assoc. lumber mills has increased by 57 per cent since 1949 to a present high of nearly 17.5 million board feet daily, a region-wide survey just completed reveals. Edwin Knight, lumber seasoning specialist at the association's research laboratory, Portland, Ore., said the survey showed virtual doubling of kiln capacity since 1943 in the 12-state Western Pine region.

The latest study disclosed kiln facilities today accommodate nearly 71 per cent of the record high annual regional lumber production of 8.658 billion feet.

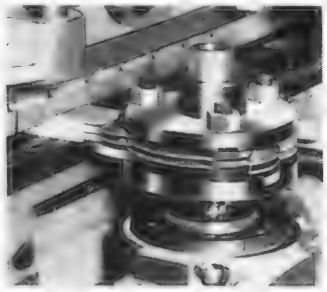
Soil Builder Process Developed at Armour Research Foundation

A soil builder process has been developed that opens up a vast potential market for bark, according to Dr. C. R. McCully, Armour Research Foundation, Chicago. Foundation scientists discovered a way to convert bark into an inexpensive and unusually effective soil builder, it is reported. In tests conducted with greenhouse plants and field crops, it was found to promote growth and improve soil better than either peat moss or a commercial soil conditioner.

NEW PRODUCTS—LITERATURE

Finger Jointing Bulletin

A bulletin containing information and recommendations on the type of machine that should be used for finger jointing is available from Wisconsin Knife Works, Beloit, Wis. Bulletin 700 contains examples of typical wood parts that are being successfully finger jointed, specifications of standard heads, dimensioned drawings of standard joints, and information on use and maintenance.



Illustrated in the photo is stock being cut by a Badger finger joint cutting head. The cutting heads are available in 8 and 10¾ inch diameters, the 8 inch head for finger joint machines, tenoners (single end), and shapers, and the 10¾ inch diameter head for double end tenoners.

Gas Chain Saw

A new direct-drive gas chain saw designed for compactness, portability, and power has been introduced by Porter–Cable Machine Co., 104 Exchange St., Syracuse, N. Y. Available with 16-, 20-, or 24-inch bar sizes, the Model 530 will reportedly provide fast and powerful cutting of logs or timber up to 48 inches in diameter.

Operating features of the saw include a recoil starter, automatic clutch that prevents stalling, and tubular steel

See page 29-A for
More New Product News

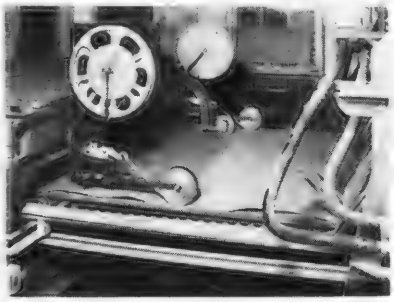
"wrap-around" handle to assure balance. A trigger-type throttle is conveniently located under the rear handle.

Weighing 24 pounds without guide bar and chain, the saw delivers 3.5 brake horsepower. Available with float or diaphragm carburetor, the saw has heavy duty bearings and neoprene seals on shaft as well as main bearings. A 32-page catalog of their portable tools is available from the manufacturer.

Veneer Tape Application

A solution for the splitting problem of edge-glued veneer has been developed at the Plylock Plant of Simpson Logging Co., Portland, Ore. It is accomplished by an application of gummed paper tape manufactured by Crown Zellerbach Corp., San Francisco.

Equipment needed for this application will reportedly: virtually eliminate splitting of face and back stock as it comes off the edge-gluer, in



handling, and in the lay-up operation; do away with reject veneer due to splitting; and save approximately 20 per cent of labor costs in panel patching operations.

As shown in the photo, a strip of 1-inch tape is automatically applied close to each edge of the veneer as it moves from the edge gluer to the clipper. The application is made by mounting two tape moistening units and 4600-foot rolls of tape on each edge of the veneer, then threading the tape through water moistening units and under the heavy brass rollers used to seal the tape to the veneer. The tape is then continuously appl d as the veneer moves to the clipper

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Positions Offered

No. E-273—West Coast organiza n has opening in engineering-research for graduate wood technologist or wo engineer with broad background in t basic sciences and intensive training in a anced wood technology. A good knowl ge of statistical methods and familiarity w h plywood manufacturing desirable. M t be able to handle shop and laborator quipment and techniques. Salary depen nt on qualifications. (May)

Employment Wanted

No. 400—Wood technology g duate, age 29, wth three years' experience particle board field in U. S. and G many, seeks position in particle board i ustry. Special background in research and quality control. (Apr.)

No. 405—University of Missou forestry graduate seeks position in forest products marketing and managemen t. Age 23, single. (Apr.)

No. 406—University of Cal fornia graduate student in production management and forest economics seeks position in logging engineering or wood waste utilization in Pacific Northwest Two years' experience as senior engi ering aide. Age 25, married. (Apr.)

No. 409—Rutgers University restry graduate, will receive Master's d ree in Forest Management and Wood tilization from Pennsylvania State Un ersity in June, seeks position in Nortl st as forest manager, logging engineer, saw-mill supervisor. Age 26, married Apr.)

No. 410—Wood technologist, 29, married, seeks position in factory lmin-istration or supervision in the rand Rapids area. 3½ years' experience pro-duction control management, two rs in supervision of lumber handling rews. (Apr.)

No. 411—Summer employment ught in forest products production, arch, or sales in South by Louisiana l tech-nic Institute student. Dallas H rson. 817 Herget, Ruston, La. (Apr.)

No. 412—June 1957 graduate Iowa State College, B.S. in wood ut ation. seeks responsible position in furnitu man ufacturing. Six years' experience i arni-ture upholstery and cabinet work ngle. age 32. (May)

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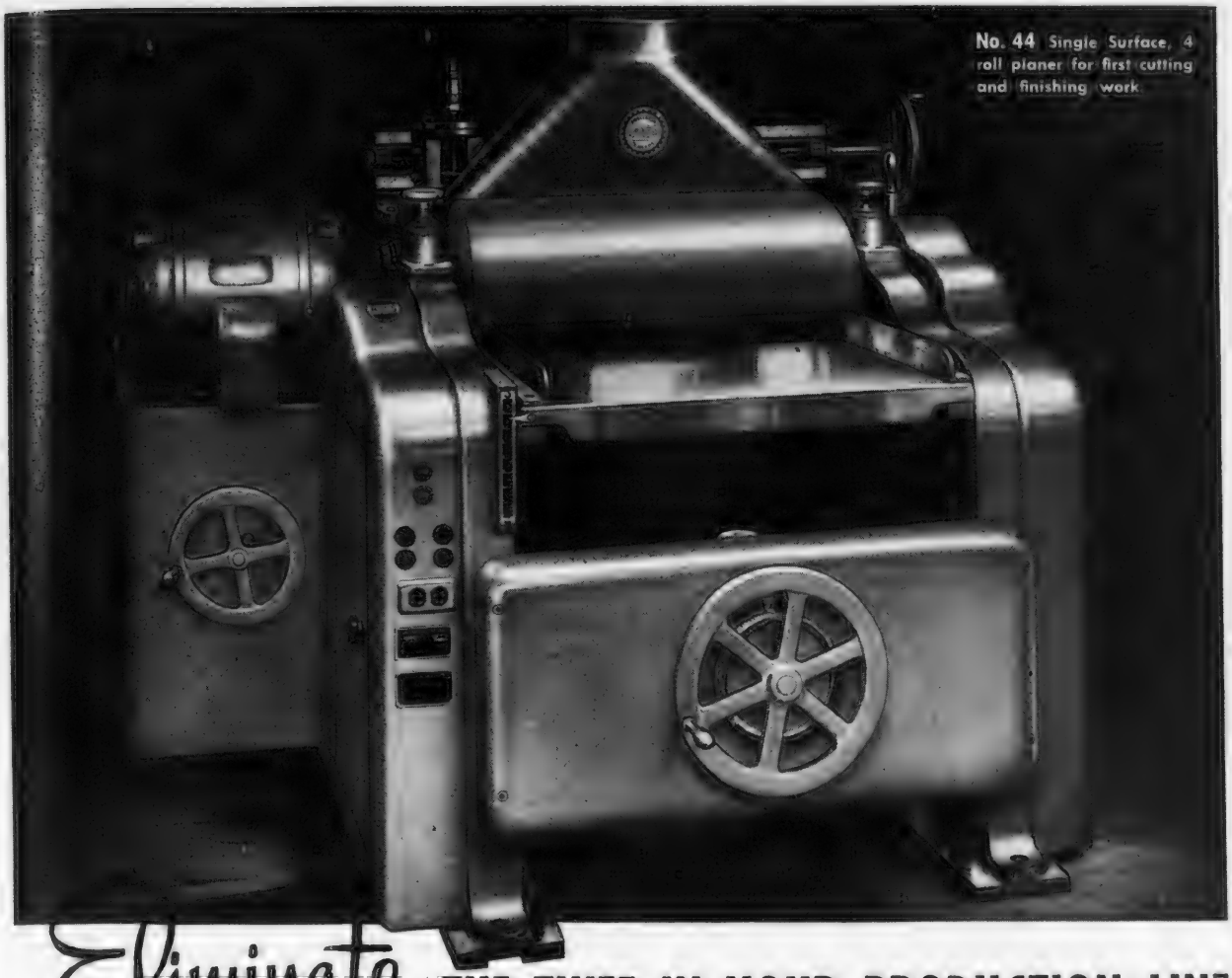

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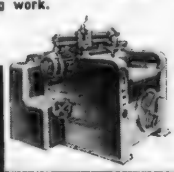
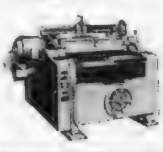
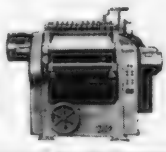


No. 66 Single Surface, 6 roll planer for first cutting and finishing work.



No. 88 Double Surface, 8 roll planer for first cutting and finishing work.

No. 55 Heavy duty Double Surfacer for planing rough lumber.



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Vol. III—1949

Raw Materials Sources; Role of Sawmills in Improved Forest Utilization; Furniture Manufacture; Gluing; Furniture Finishing; Rotary Veneer Cutting; Molding Plywood; Chemical Utilization; Preservation; Laminated Wood Trusses; Research and Development; Seasoning.

Vol. IV—1950

Logs, Sawmills and Lumbering; Containers; Pulpwood and Pulp; Quality Control; Particle Board; Softwood Plywood; Gluing Operations; Hardboard; Wood Waste Utilization; and other general subjects (impregnation, preservatives, plywood, fibers.)

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FOREST PRODUCTS RESEARCH SOCIETY

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OBJECTS *and* PURPOSES . . . The objects and purposes of this Society shall be . . .

1) To facilitate the interchange of information among individuals and organizations who are interested in forest products research, development, or utilization
   - *a)* by abstracting papers, reports, and other publications,
   - *b)* by publishing and distributing pertinent information,
   - *c)* by encouraging cooperation among interested persons,
   - *d)* by promoting standard test methods and procedures,
   - *e)* by sponsoring meetings for the presentation and discussion of reports of investigations and experiences of its members and others, for the interchange of ideas, and for the broadening of acquaintanceships among individuals interested in forest products research, development, or utilization; and

2) in general, to encourage and promote the efficient utilization of wood and other forest products.

EXTRACTS FROM BY LAWS

MEMBERSHIP . . . The Society shall consist of Voting Members, Associate Members, and Supporting Members.

A Voting Member shall be any individual who is actively engaged in planning, supervising, or working in any phase of forest products research, development, or utilization. Voting members shall have all rights and privileges of the Society.

An Associate Member shall be any individual who is interested in forest products research, development, or utilization although not actively engaged in such activities. Associate members shall have all rights and privileges of Voting Members, except those of holding office and voting.

A Supporting Member shall be any organization or individual who financially assists the Society by paying larger dues. Supporting Members may designate a representative who shall have all rights and privileges of Voting Members.

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FPRS Forest Products Journal

Vol. VII, No. 4
April, 1957

Quality Control in Sanding Particle Board

DAVID A. HAILE

Resinwood Products Division, Rock Island Millwork Co., Rock Island, Ill.

The over-all need for close tolerances in machining particle board are dictated by the product's end use. Sanding equipment in use to obtain the required thickness tolerance for a particular product is described and a method explained for evaluating and maintaining this tolerance. Production records are presented as evidence of these studies in actual practice.

THE ABSENCE OF QUALITY CONTROL in the manufacture of a product often leads to the production of non-uniform material which in turn results in more waste for both the producer and consumer. This waste is reflected in higher costs and therefore a less attractive value for the product.

Particle board production requires an extremely acute sense of the control of its quality. The particle board industry in this country, since it is so new and versatile, demands that each producer provide a quality product and adequate guidance in the proper end use of the product. The production of a low quality product combined with lack of knowledge of the limitations of the product can impair the growth of the entire industry.

In many cases the equipment is on hand or purchased before sufficient experience or planning can direct the wisest choice of such equipment. Possible limitations of this equipment may affect selection of specifications for the product and emphasize the importance of quality control procedures.

Quality control not only insures a knowledge of the limitations of the product, but makes it possible to more efficiently use the equipment. In most cases, it makes it possible to produce a product of sufficiently high quality on "have already" machinery. This is an important, and much overlooked, phase of statistal quality control activities.

A number of properties of particle board may be important when considering quality control:

1. Modulus of rupture
2. Tensile strength parallel to surface
3. Water absorption
4. Density
5. Hardness
6. Abrasion resistance
7. Dimensional stability
8. Tension perpendicular to the surface
9. Glue line shear
10. Impact
11. Screw holding
12. Lateral nail holding
13. Nail head pull through
14. Shear parallel to the surface
15. Moisture content
16. Sizes and tolerances
    - A. Length
    - B. Width
    - C. Squareness
    - D. Thickness

Obviously not all of these properties have the same degree of importance in the wide range of particle board end uses. Resistance to abrasion, for example, would be of prime importance in bench top surfacing particle board, whereas this property holds little significance in a core stock particle board. The end use for the product ordinarily suggests the most important variables to control.

Resincore, the product with which this paper is concerned, is a high density core stock for "one shot" high pressure laminating. It compresses about 0.015 inch when hot pressed under 500 psi at 300° F. for 15 minutes.

Therefore to produce a satisfactory core which will not cause "clouded areas" in the overlay of the finished product, the thickness tolerance within each sheet must be controlled to less than 0.015 inch. Naturally there are other products involved, such as multiple "lay ups" etc., which require even better tolerances. However, this paper

[1] Presented at Session IX, Wood Machining, FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

The Author: D. A. Haile attended Northwestern University and worked in the research laboratory of Minnesota and Ontario Paper Co. before joining his present employer in 1950.

Fig. 1.—Boards coming from trim saws.

Fig. 2.—Boards going to sander.

Fig. 3.—Boards coming from sander.

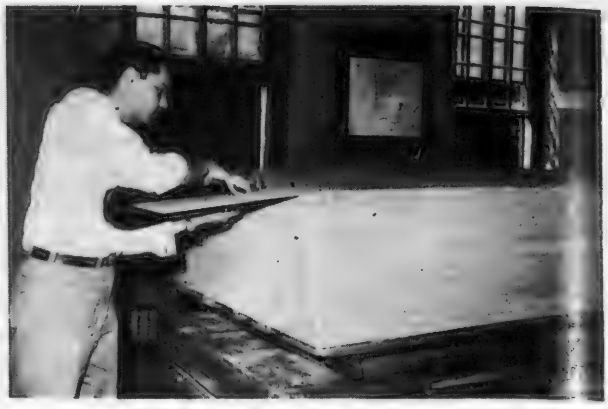


Fig. 4.—Quality control check of thickness.

will not attempt to discuss extenuating variables affecting thickness tolerance requirements.

Having established the desired tolerance, it is necessary to analyze the available equipment to determine its capabilities. This requires a working knowledge of statistical quality control.

The sanding esquipment now in use for Resincore is a Yates S-800. A Durite and/or Trimite paper is used. This is a combination back silicon carbide abrasive. Numbers 40, 60, 80, and 100 grit are used. The tests boards described in this paper were sanded at a speed of 32 feet per minute.

The boards are palletized in the press room and thereafter handled with a lift truck to the trimmer feed table. From the trimming operation they are carried by a conveyor to the sander and through the sander, after which the material receives its final inspection (Figs. 1–4).

To assume that the sander will provide the necessary tolerance alone is extremely erroneous. The production of a board of uniform thickness tolerance emanates from the preparation and mixing operation of the manufacturing process. Poor mixing and nonuniform basic materials create added thickness variation in the final board. Spreading the proper amount of material in the tray and uniformly throughout the tray is a prerequisite of a uniform tolerance after sanding. The actual pressing technique employed affects the tolerance too, since it must produce a board of optimum thickness for full surface clean up and no excess thickness above that necessary for good clean up. The sequence of operations is shown in Fig. 5.

Although sanding is an important operation in producing a board within the desired thickness tolerance and surface quality, it must be remembered from the foregoing, that it is only one step in achieving proper thickness tolerance.

Procedure

The following analysis is presented in detail for purposes of instruction and discussion of the procedure used to determine the specifications for the end product.

1. 100 boards of 1/4-inch 7025D Resincore were taken from the trim saws—unsanded.

2. Each board was measured for thickness in 20 different areas on the board. Each board was numbered from 1–100.

3. These boards were then sanded as close to 0.250 inch as the machine and operators could obtain.

4. Each board was measured for thickness in 20 different areas. The numbers were recorded on the board again for checking tolerance of the same board before and after sanding.

Table 1 is one page of the test data collected on this 100-board run, and represents 8 boards. Columns 1–8 and 1a–8a refer to the board before and after sanding, respectively. The values for R, T, X, and σX are 0.001 inch. The column of figures pertaining to the unsanded board have a zero point of 0.287 inch. The column of figures pertaining to the sanded board have a zero point of 0.250 inch.

Explanation of terms:

R: Range—mathematical difference between highest and lowest measurement in the board. E. g. board No. 1 is $(+3) - (-12) = 15$ or .015 inch variation.

T: Total—means mathematical total of coded figures. Board No. 1 is —113.

X: Average thickness—obtained by dividing T by 20 (No. of measurements). Board No. 1 is —5.7. This means that the average thickness of this board is $0.287 - 0.0057 = 0.2813$ inch or 0.281 inch.

fu_i^2: The sum of squares of individual measurements.

nfu_i^2: No. of measurements per board multiplied by fu_i^2.

T^2: $(fu_i)^2 = T^2$.

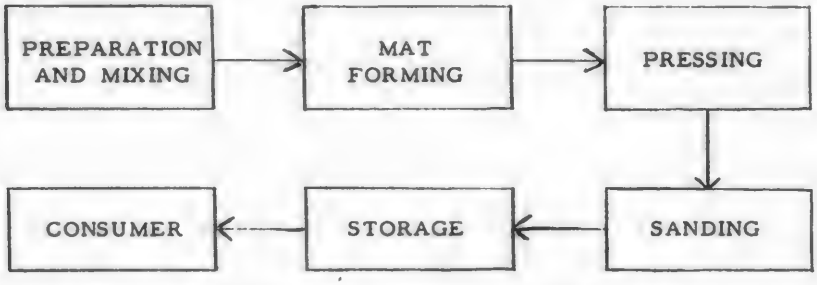
$\sigma\mu$ = Standard deviation — root mean square — not to be confused with Mean Deviation.

For complete reference to method of analysis and derivations of formula $\sigma\mu = \frac{\sqrt{nfu^2 - (fu_i)^2}}{n}$, see Engineering Statistics and Quality Control, page 57.

Example of calculation:

BOARD NO. 1—UNSANDED

X_i	f_i	u_i	$f_i u_i$	u_i^2
275	3	12	36	432
276	3	11	33	363
277	0	10	0	0
278	2	9	18	162
279	1	8	8	64
280	1	7	7	49
281	0	6	0	0
282	1	5	5	25
283	2	4	8	32
284	0	3	0	0
285	3	2	6	12
286	0	1	0	0
287	1	0	0	0
288	0	+ 1	0	0
289	1	+ 2	+ 2	4
290	2	+ 3	+ 6	18
	20		—113	1161



FACTORS INFLUENCING THICKNESS TOLERANCE

Fig. 5.—Factors influencing thickness tolerance.

Table 1.—CONTROL CHART FOR EIGHT BOARDS, STANDARD THICKNESS .287–.250 INCH

	1	1a	2	2a	3	3a	4	4a	5	5a	6	6a	7	7a	8	8a
	−12	1	5	1	−16	0	−10	0	2	3	− 4	2	−10	0	20	4
	−11	1	− 7	0	−17	1	−14	0	5	2	− 3	2	−12	2	7	1
	−11	1	−10	0	−16	1	−17	0	3	4	− 2	3	− 8	1	− 1	5
	11	1	− 4	3	−12	1	−16	1	3	3	1	4	− 4	3	1	2
	− 8	1	8	0	− 9	2	−11	0	4	2	2	1	− 5	0	23	0
	2	− 2	10	− 1	− 7	1	− 7	1	5	0	5	0	− 1	1	23	− 1
	9	1	− 3	2	−12	− 1	−17	1	0	2	3	1	− 2	3	− 3	2
	9	1	12	− 2	−17	− 2	16	3	2	2	3	0	− 7	0	− 3	0
	− 4	− 1	− 4	− 1	−15	− 3	−12	4	− 1	2	− 3	0	−10	− 1	3	− 2
	2	− 1	6	− 2	−13	− 2	−12	4	0	1	6	− 2	− 9	− 3	15	− 3
	3	− 1	12	0	− 5	0	− 5	1	3	0	9	2	− 4	1	13	0
	2	2	− 7	− 1	− 5	1	−14	1	2	0	3	0	− 2	0	− 3	0
	5	1	−10	0	− 8	− 1	− 17	3	7	0	4	0	− 3	0	− 3	1
	4	0	0	0	−12	− 2	−11	0	0	0	− 2	1	− 8	1	− 7	0
	3	1	18	1	−12	− 1	− 7	0	2	1	− 2	1	− 9	0	22	1
	− 2	2	20	3	0	0	− 8	3	3	3	− 3	3	− 3	2	22	3
	12	1	− 2	− 1	9	3	15	2	1	1	− 3	0	9	0	3	0
	12	− 1	0	0	− 6	− 2	13	1	2	0	5	− 1	4	0	3	0
	7	− 1	7	0	− 2	− 1	7	2	3	1	9	0	5	0	10	0
	0	0	16	0	− 2	0	− 3	− 2	4	0	9	1	4	0	24	− 1
R	15	4	32	5	26	6	14	7	12	6	15	6	21	6	27	8
T	−113	5	43	2	−177	7	232	−19	14	17	11	18	−75	10	183	12
X	− 5.7	− .3	2.2	.1	− 8.9	− .4	−11.6	− 1.0	.7	.9	.6	.9	− 3.8	.5	9.2	.6
fu^2	1,161	27	1,885	36	2,429	47	3,040	77	198	67	441	56	905	40	3,659	76
nfu^2	23,220	540	37,700	720	48,580	940	60,800	1,540	3,960	1,340	8,820	1,120	18,100	800	73,180	1,520
T^2	12,769	25	1,849	4	31,329	49	53,824	361	196	289	121	324	5,625	100	33,489	144
$\sqrt{nfu^2 - t^2}$	102	22.7	189.4	26.8	131.3	29.8	83.5	34.4	61.3	32.4	93.3	28.2	111.7	26.5	199.2	37.1
σx	5.1	1.1	9.5	1.3	6.6	1.5	4.7	1.8	3.1	1.7	4.7	1.4	5.6	1.3	10.0	1.9

$$\sigma\mu = \frac{\sqrt{20 \times 1161 - (-113)^2}}{20}$$

$$\sigma\mu = \frac{\sqrt{10{,}451}}{20} = 5.1$$

All charts are based on 0.001 inch units.

Fig. 6 shows the average board thickness for each of the eight boards both before and after sanding. It can be seen that approximately .035 inch are removed from the board in the sanding operation.

Fig. 7 shows the standard deviation both before and after sanding. The standard deviation chart is used in addition to the range chart to better indicate "wedge" sanded boards.

Fig. 8 shows the range of thickness within each board before and after sanding.

It should be noted that thickness tolerances will change on this type of material due to storage conditions since it is necessary to make it "dry" for the laminator. Therefore, controlled storage conditions and/or "made to order" material is recommended for this type of product.

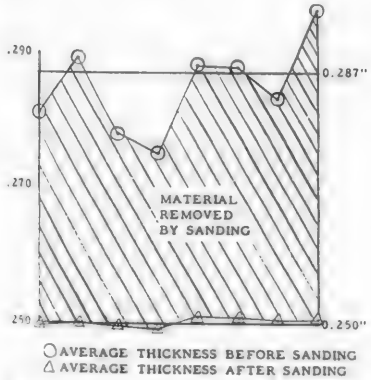


Fig. 6.—Average thickness for eight boards before and after sanding.

Conclusions

1. A realization of the need for producing a quality board is necessary before a quality board can be produced.
2. The sanding operation of the particle board is only one phase of producing a board of acceptable thickness tolerance.
3. A close producer-consumer relationship must exist to:
   a. Use the material where it should be used.
   b. Work out special shipping arrangements for quick use of specially prepared "dry" board.

Discussion

Ray Campbell (Wynnewood Products Co.): Do you sand the board hot?

Mr. Haile: We do occasionally sand a load directly from the press but as a rule the material is sanded 6 to 24 hours after manufacture.

Mr. Campbell: How many high density boards do you sand before you change papers?

Mr. Haile: That depends on many things, and particularly on the finish desired. Our end use allows us about 1200–1500 sheets.

J. R. Stillinger (Cascades Plywood Corp.): What is the moisture content coming out of press?

Mr. Haile: Moisture content in dry board is between 3 and 4 per cent; in wet board it is between 5 and 6 per cent.

Mr. Stillinger: What was your experience in range and standard deviations in each sheet and between sheets?

Mr. Haile: The individual variations were 7/1000; sheet to sheet, 9½/1000.

R. V. Reynolds (Kennametal, Inc.): If the material were planed before sanding, would it improve quality of thickness tolerance?

Mr. Haile: I do not have experience with planing board of this density.

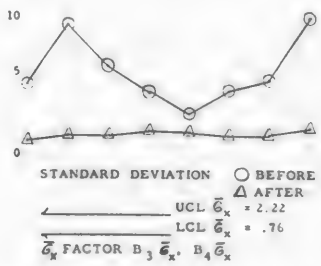


Fig. 7.—Standard deviation before and after sanding.

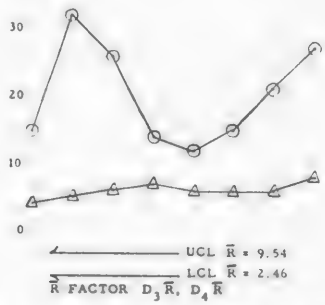


Fig. 8.—Range of thickness within each board before and after sanding.

Influence of Fungus Infection Associated with Chemipeeling on Pressure Impregnation and Cold Soaking of Jack Pine Posts[1]

EDWARD PANEK

Technologist, Forest Products Laboratory[2], Forest Service, U. S. Dept. of Agriculture

Air-seasoned, round jack pine posts that were chemi-peeled and infected with fungi, were treated by cold soaking and by pressure impregnation. Fungus infection associated with the use of arsenic increased penetrations and retentions of preservative in chemi-peeled posts in cold-soaking treatments. Killing the trees with arsenic, without permitting time for fungi to visibly develop, exerted only slight influence on the results of treating jack pine posts.

Introduction

IN AN EXPLORATORY STUDY in 1952, jack pine posts cut from trees that were girdled and poisoned with sodium arsenite solution absorbed approximately three times as much preservative, when treated by cold soaking in preservative oil, as jack pine posts cut from green trees that were peeled and seasoned in the conventional manner. Similar results were noted later in the cold-soaking treatment of red pine posts.

It is known that the presence of common green *Trichoderma* mold, decay, and blue stain fungi in pine sapwood increase penetration and retention of preservatives.[3,4] It is also known that *Trichoderma* often develops profusely on wood surfaces treated with fluorine-containing solutions, and that several fungi are similarly associated with the use of arsenic solutions.[5] The purpose of this work, therefore, was to study fungus infection as a possible reason for the results obtained in the preservative treatment of posts from arsenic-killed trees.

Jack pine posts produced from arsenic-poisoned and unpoisoned trees in a manner designed to either limit or encourage the growth of mold fungi were treated by cold soaking and pressure impregnation.

Material

The jack pine *(Pinus banksiana)* posts were obtained through the cooperation of the North Central Region of the Forest Service from on even-aged stand on the Lakewood District of the Nicolet National Forest in Wisconsin. Fifty trees were cut, each of which had a breast-high diameter of not over 6 inches, and was tall enough to furnish three posts 6½ feet in length with a top diameter of the uppermost post not less than 3 inches. The 50 trees thus gave a total of 150 posts, or 10 for each of 15 test variables, which included three different treatments and five different post types. Each post was identified as to tree number and position in the tree. The butt, middle, and top posts from the trees were evenly distributed over the five different post types, and a random selection was then made for the different charges for each of the three treatments.

The five post types were as follows:

Posts From Unpoisoned Trees: The posts from unpoisoned trees were cut on June 2, 1954, and were taken to the Laboratory and peeled within two days.

1. Mold growth discouraged.—The posts in which mold growth was to be discouraged were dipped in a 3 per cent sodium pentachlorophenate solution.

2. Mold growth encouraged.—The posts in which mold growth was to be encouraged were sprayed with a 3 per cent sodium fluoride solution, and were bulk piled under a tarpaulin for 16 days to encourage *Trichoderma* mold growth. When the posts were covered with a heavy growth of the mold, the tarpaulin was removed to permit some seasoning and to allow time for the mold to penetrate the wood. Two weeks later, the posts were open piled to hasten seasoning.

3. Controls.—Control posts received no treatment to limit or to encourage mold growth.

Posts From Poisoned Trees: The trees were poisoned on June 2, 1954, by applying sodium arsenite solution with a brush to a 6-inch girdle made at stump height. The sodium arsenite solution was prepared with 4 pounds of arsenic trioxide, 1 pound of sodium hydroxide, and enough water to make a gallon of solution. Care was taken to avoid cutting into the wood when the girdles were made.

4. Posts cut one week after poisoning.—One group of posts was cut 1 week after the trees were poisoned to provide time for the arsenic to kill the trees, yet not allow sufficient time for mold or other fungi to become established in the wood. These posts were peeled within two days after they were cut, and were then dipped in a 3 per cent sodium pentachlorophenate solution to discourage mold growth.

5. Posts cut four months after poisoning.—The fifth group of posts was cut four months after the trees were poisoned to provide an opportunity for fungus growth.

After all posts were prepared, they were air seasoned in an open shed. Moisture-meter readings from representative posts prior to treatment are given in Table 1.

Posts cut from unpoisoned trees during early June were easily slip-peeled; those poisoned during early June and cut one week later were difficult to peel without a drawshave, and those cut four months after the trees were poisoned had most of the bark loosened, although patches of bark around knots adhered and required removal with a drawshave. The group cut after four months showed light surface attack by insects, possibly bark beetles.

The posts were trimmed to a 6 foot length prior to treatment. They were then carefully examined on all surfaces for evidence of fungus growth. Posts from poisoned and unpoisoned trees that were dipped in a 3 per cent sodium pentachlorophenate solution showed no evidence of infection. The unpoisoned posts sprayed with a 3 per

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[1] Since this study was completed in May 1955, others have studied the treatability of chemi-peeled southern yellow pine. They include Huffman and Birdsall, whose work is reported in the 1955 and 1956 Minutes of the Coordinated Wood Preservation Council.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Lindgren, R. M. 1952. Permeability of southern pine as affected by mold and other fungus infection. American Wood Preservers' Association Proc., pp. 158–168.

[4] Blew, J. O., Jr. 1952. Treatability of southern yellow pine as influenced by fungus infection. Jour. For. Prod. Res. Soc. II (3):85–86.

[5] Scheffer, T. C. and R. M. Lindgren. 1940. Stains of sapwood and sapwood products and their control. U.S.D.A. Tech. Bull. No. 714.

The Author: Edward Panek holds a B. S. degree in Forestry from the University of Minnesota. He was in the Administrative Branch of the U. S. Forest Service before joining the Forest Products Laboratory staff.

Table 1.—MOISTURE-METER READINGS ON JACK PINE POSTS PRIOR TO TREATMENT

Group	Moisture-meter readings* at various depths: ½ inch Per cent	1 inch Per cent	1½ inches Per cent
1. [illegible]poisoned, treated to discourage mold [illegible]wth	14	15	16
2. [illegible]noisoned, treated to encourage mold [illegible]wth	13	14	14
3. [illegible]poisoned, controls	13	14	15
4. [illegible]soned, treated to discourage mold [illegible]wth	14	15	16
5. [illegible]oisoned, cut after opportunity for fungal [illegible]wth	13	14	15

*alues are the average of three readings.

cent sodium fluoride solution showed no evidence of blue stain or decay, but the wood was somewhat "off color" due to the penetrating mold growth. Nine of the 30 unpoisoned control posts showed blue stain covering from 1 to 18 per cent of the cross-sectional area of the ends, while the other 21 posts appeared to be free of infection. The poisoned posts cut four months after the trees were girdled showed blue stain an other discoloration, indicating incipient decay, that covered from 15 to 92 per cent, and averaged about 48 per cent, of the cross-sectional area of the ends.

Sections from one or more posts of each type were examined microscopically. This examination showed no apparent infection in the section from the unpoisoned post dipped in 3 per cent of sodium pentachlorophenate, and, with few exceptions, the ray parenchyma cells were closed. An abundance of fungus hyphae, mostly of the mold type, was found in the section from the unpoisoned post sprayed with sodium fluoride, particularly in the ray parenchyma cells, and most of the ray cells were open. Scattered hyphae of fungi were found, mostly in the ray parenchyma cells, in the sections from the unpoisoned control posts and the section from the poisoned post cut one week after girdling. The rays in these sections, however, were usually closed. An abundance of fungus hyphae of several types, including molds and stains, was found in the section from the poisoned post cut four months after girdling, and the ray cells were mostly open.

Treatment

The treatments were started April 29 and were completed May 19, 1955. The preservative used was a 50–50 solution of coal-tar creosote meeting AWPA Standard P1, and No. 2 fuel oil meeting Commercial Standard 12–48. Ten posts of each of the five types were treated by each of the following methods: (1) cold soaking for 6 hours, (2) cold soaking for 48 hours, and (3) pressure impregnation.

The cold-soaking treatments were made in an open tank in which the posts, in a horizontal position, were completely submerged in the preservative. The posts were removed from the preservative and weighed during the course of and at the end of the soaking period to obtain retentions at intermediate intervals as well as for the total soaking period. Posts treated for 6 hours were weighed at the end of 1- and 3-hour soaking periods, and were then returned to the tank to complete the soaking period. Posts soaked for a total of 48 hours were weighed at 1-, 3-, 6-, and 24-hour periods as well as at the 48-hour period. To remove surplus preservative, the posts were permitted to stand on end and drain for five minutes before each weighing. The temperature of the unheated preservative was taken at least once each day during the treatments, and varied from 76° to 89° F. Variation in temperature during any one treatment did not exceed 5° F., however.

The pressure treatment was made by the Rueping empty-cell process in the Laboratory's 6-foot cylinder. An initial air pressure of 75 pounds per square inch was applied for 15 minutes, following which the cylinder was filled with preservative at room temperature (approximately 80° F.) without varying the pressure. When the cylinder had been filled, the pressure was raised to 150 pounds per square inch and held there for one hour. The pressure was then released, the cylinder was drained of preservative, and a final vacuum equivalent to about 27 inches of mercury was applied for 30 minutes. The individual posts were weighed before and after treatment to determine preservative retentions.

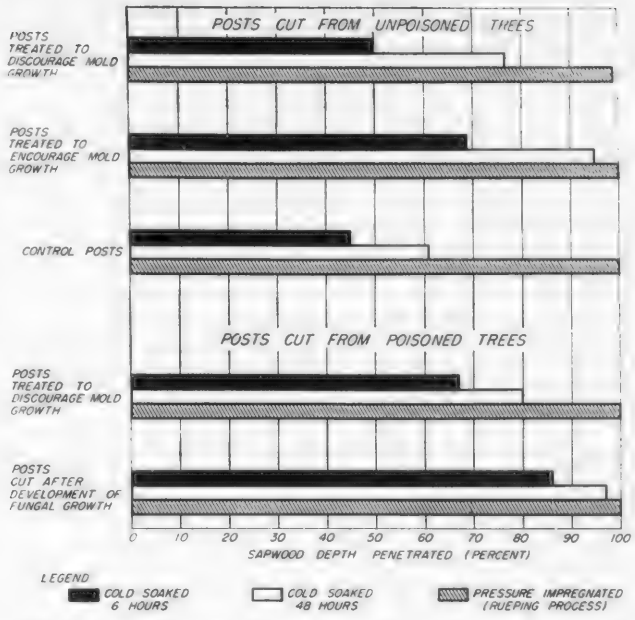
POSTS CUT FROM UNPOISONED TREES
POSTS TREATED TO DISCOURAGE MOLD GROWTH
POSTS TREATED TO ENCOURAGE MOLD GROWTH
CONTROL POSTS
POSTS CUT FROM POISONED TREES
POSTS TREATED TO DISCOURAGE MOLD GROWTH
POSTS CUT AFTER DEVELOPMENT OF FUNGAL GROWTH
0 10 20 30 40 50 60 70 80 90 100
SAPWOOD DEPTH PENETRATED (PERCENT)
LEGEND
COLD SOAKED 6 HOURS
COLD SOAKED 48 HOURS
PRESSURE IMPREGNATED (RUEPING PROCESS)

Fig. 1.—Average depth of penetration of coal-tar creosote—No. 2 fuel oil solution in the groundline zone of jack pine posts.

Results of Treatment

Twenty-four hours after treatment, the posts were sawed through longitudinally to permit measurements on sapwood depth and preservative penetration. One of the sawed sections of each post was surfaced, and measurements were taken immediately on opposite sides 30 inches from the butt end (groundline) and 6 inches from the top end.

From the data in Table 2 and the bar graphs in Figs. 1 and 2, which show the average penetrations and retentions of preservative, it may be noted that the results of treatment were influenced by the extent of fungus development in the wood, particularly when the posts were treated by cold soaking. Control posts and groups of posts from poisoned and unpoisoned trees that were treated to discourage mold growth showed average preservative retentions of from 0.8 to 1.2 pounds per cubic foot when cold soaked for six hours. The posts from unpoisoned trees that were treated to encourage mold growth and the posts from poisoned trees that were cut after an opportunity for infection showed average retentions of 6.1 and 9.0 pounds per cubic foot, respectively, when cold soaked for six hours. Preservative retentions increased with the longer soaking periods, but the trend in retentions was the same.

Average retentions of the pressure-treated groups varied, but the differential between the infected and uninfected posts was not so great as with the cold-soaking treatments. The difference in retention, however, appeared to be sufficient to justify segregation of the arsenic-killed and mold-infected

posts from uninfected posts in pressure treatment. A probable explanation of the more limited variation in retention after pressure treatment is that the preservative that was injected into the more easily penetrated, infected wood during the pressure period was also more easily removed during the "kick-back"[6] and during the final vacuum.

[6] Preservative forced out during release of pressure.

With the average preservative retentions for the unpoisoned control posts shown as 100 per cent, the influence of other test variables is shown by comparison in Table 3. Posts from arsenic-killed trees that were cut before mold growth visibly developed showed average retentions only slightly greater than those for the control posts. Posts from unpoisoned trees with stimulated mold growth, however, and particularly those from arsenic-killed trees left standing long enough for mold and other fungus development, showed much higher retentions than the control posts after the cold-soaking treatment.

Preservative penetrations followed trends similar to those noted for preservative retentions, with the infected posts (induced or from trees left standing long enough for molds and other fungi to develop) showing a higher percentage of sapwood depth penetrated in the 6- and 48-hour cold-soaking treatments than the control posts or posts in which an attempt was made to retard mold growth. Penetrations in the cold-soaking treatment were greater for infected posts than for uninfected or partially infected posts, but the difference was less than the differences noted in preservative retentions. Posts from arsenic-killed trees that were cut before infection developed noticeably showed some improvement in penetration over the control posts, while posts from arsenic-killed trees left standing long enough for infection to develop showed better penetrations than the mold-infected posts from unpoisoned trees.

Practically all the pressure-treated posts were penetrated to 100 per cent of the sapwood depth, and penetrations, therefore, were not noticeably influenced by infection.

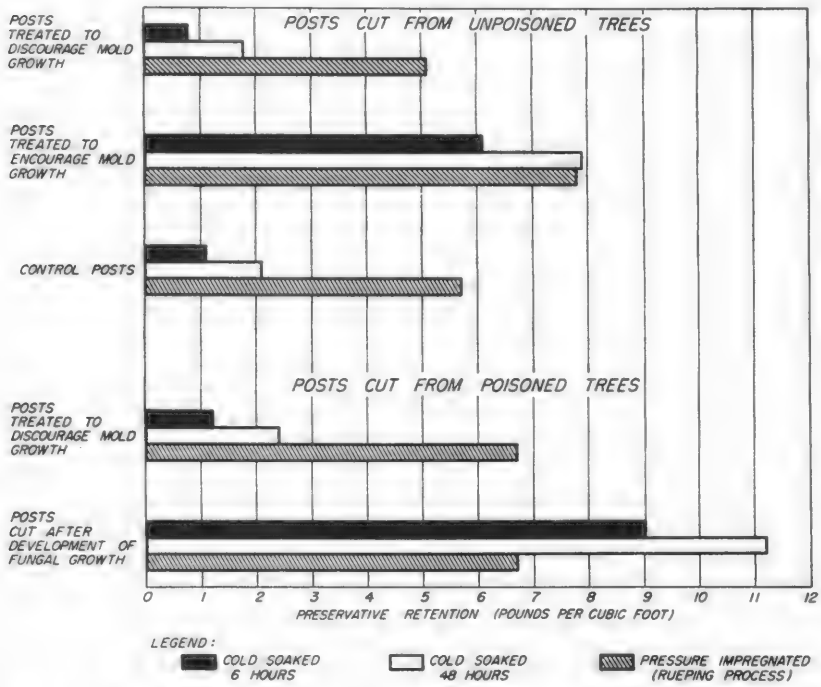
POSTS CUT FROM UNPOISONED TREES
POSTS TREATED TO DISCOURAGE MOLD GROWTH
POSTS TREATED TO ENCOURAGE MOLD GROWTH
CONTROL POSTS
POSTS CUT FROM POISONED TREES
POSTS TREATED TO DISCOURAGE MOLD GROWTH
POSTS CUT AFTER DEVELOPMENT OF FUNGAL GROWTH
0 1 2 3 4 5 6 7 8 9 10 11 12
PRESERVATIVE RETENTION (POUNDS PER CUBIC FOOT)
LEGEND:
COLD SOAKED 6 HOURS
COLD SOAKED 48 HOURS
PRESSURE IMPREGNATED (RUEPING PROCESS)

Fig. 2.—Average retention of coal-tar creosote—No. 2 fuel oil solution in jack pine posts.

Conclusions

1. Fungus infection associated with the use of arsenic in chemi-peeled posts significantly increased preservative re-

Table 2.—RESULTS OF TREATMENT OF JACK PINE POSTS

	Posts cut from unpoisoned trees, and treated to discourage mold growth			Posts cut from unpoisoned trees, and treated to encourage mold growth			Control posts			Posts cut from poisoned trees: 1 week after girdling, and treated to discourage mold growth			Posts cut from poisoned trees after the development of fungus infection		
	Cold soaking 6 hours	Cold soaking 48 hours	Rueping pressure process	Cold soaking 6 hours	Cold soaking 48 hours	Rueping pressure process	Cold soaking 6 hours	Cold soaking 48 hours	Rueping pressure process	Cold soaking 6 hours	Cold soaking 48 hours	Rueping pressure process	Cold soaking 6 hours	Cold soaking 48 hours	Rueping pressure process
Preservative retention (Lb. per cu. ft.)															
Minimum	0.7	1.3	4.1	3.2	5.9	6.5	0.6	1.6	4.8	1.0	1.6	5.0	2.3	5.2	5.1
Maximum	1.1	2.9	6.5	9.3	11.9	8.6	2.2	3.0	6.9	1.5	3.4	8.4	18.0	14.6	7.6
Average[1]	.8	1.8	5.1	6.1	7.9	7.8	1.1	2.1	5.7	1.2	2.4	6.7	9.0	11.2	6.7
Standard deviation	.1	.6	.9	1.9	2.1	.7	.4	.5	.7	.1	.6	1.1	5.1	3.1	.9
Sapwood depth (In.)															
Minimum	.92	1.09	.85	1.02	1.30	1.20	1.26	1.35	1.35	1.16	1.15	1.10	1.29	1.31	1.23
Maximum	1.66	1.72	1.60	1.86	1.89	1.99	1.88	2.12	1.90	1.58	1.62	1.48	1.72	1.75	1.74
Average[1]	1.31	1.39	1.29	1.51	1.53	1.55	1.57	1.62	1.54	1.32	1.35	1.31	1.48	1.49	1.47
Standard deviation	.21	.21	.21	.23	.19	.24	.19	.25	.18	.13	.16	.13	.13	.16	.11
Preservative penetration (In.)															
Minimum	.18	.68	1.14	.63	1.15	1.20	.01	.40	1.35	.54	.50	1.10	.88	1.20	1.23
Maximum	.96	1.40	1.85	1.38	1.80	1.99	1.52	1.42	1.90	1.08	1.43	1.48	1.78	1.70	1.74
Average[1]	.66	1.07	1.37	1.03	1.46	1.56	.69	.96	1.54	.87	1.09	1.33	1.30	1.45	1.48
Standard deviation	.24	.25	.25	.22	.21	.24	.44	.30	.18	.16	.28	.14	.29	.15	.11
Sapwood depth penetrated (Percent)															
Minimum	16	45	94	40	85	100	1	30	97	44	37	100	59	86	100
Maximum	79	100	100	100	100	100	94	96	100	93	100	100	100	100	100
Average[1]	50	77	99	69	95	100	45	61	100	67	80	100	86	97	100
Standard deviation	19	16	2	17	6	0	29	22	1	14	17	0	14	6	0

[1] Average value for 10 posts.

tentions and improved preservative penetrations in cold-soaking treatments.

2. Cutting and peeling the chemi-peeled posts within one week, and treating the posts to retard mold growth, resulted in preservative retentions similar to those obtained in cold-soaking normal jack pine posts, but penetrations were somewhat better.

3. Fungus infection associated with chemi-peeling had a much less significant effect on preservative retentions in pressure treatment by the Rueping process than was noted in cold-soaking treatments. The sapwood was penetrated 100 per cent by the pressure treatment, and therefore the influence of mold infection and chemi-peeling was not apparent.

Table 3.—COMPARISON OF PRESERVATIVE RETENTIONS IN JACK PINE POSTS OF DIFFERENT TYPES

Post group	Average retention, based on unpoisoned control posts as 100 per cent		
	Cold soaking 6 hours Per cent	Cold soaking 48 hours Per cent	Pressure impregnation Per cent
1. Unpoisoned, treated to discourage mold growth	73	86	89
2. Unpoisoned, treated to encourage mold growth	555	376	137
3. Unpoisoned, controls	100	100	100
4. Poisoned, treated to discourage mold growth	109	114	118
5. Poisoned, cut after opportunity for fungal growth	818	533	118

Industrial Noise Problem in the Woodworking Field[1]

NOEL S. SYMONS

The potential gravity of the industrial noise problem is discussed in relation to the socio-economic, political, and legal considerations involved. New York State laws are cited to illustrate the effect of this problem on compensation systems. Recent developments in various states regarding claims for hearing losses are discussed. Methods are explained for reducing injurious noise levels, which not only cut loss-of-hearing claims but produce such collateral benefits as increased production, decreased absenteeism, and decreased accidents.

THE INDUSTRIAL NOISE PROBLEM is complex because it involves many socio-economic, political, and legal considerations, as well as "the disciplines of psychology, biology and physics, and their practical application in audiology, otology and acoustical engineering" (1).[2] Its gravity stems from the increasing demand by employees that they be compensated for loss of hearing due to exposure to hazardous noise levels in industry, and from the growing tendency of the courts to uphold awards for this condition even though the worker continues on the job and sustains no wage-loss as a result of his hearing impairment (2).

The problem is far-reaching in its implications. It affects the rights and the obligations of the individual, of employers, of insurance carriers, and of the public which pays the cost of all compensation awards in the cost of the manufactured product or of the service rendered.

There have been statements made by responsible authorities that the potential hearing loss claims in the United States could amount to from $2 billion to $7 billion. If these estimates are correct, this simply means that the *potential* loss on this type of claim alone, if such claims should be made compensable in every state, *could* exceed our present losses of all types, excluding loss of hearing, by almost 100 per cent or perhaps more. If we cut this figure in half, or even take 25 per cent of it, the possible cost of these cases on a nation-wide scale is staggering.

The impact of the problem on the industry of the different states will, of course, vary depending on the attitude of the legislative bodies and of the courts in such states, and also, of course, upon the pressures exerted by labor and industry.

However, as illustrative of industry's growing concern, a word about the potential gravity of the problem in New York State is pertinent. At the present time awards in New York are not payable until after the employee has been separated from the injurious exposure for a period of at least six months to permit the permanency of the loss to be determined. This is based upon the theory that part of the loss may be a temporary, reversible fatigue (i. e. a loss from which there may be a recovery) as distinguished from permanent nerve degeneration. This time limitation is known as the "six-month waiting period". It is an administrative ruling adopted by the Workmen's Compensation Board based on the recommendations of a Committee of Consultants on Occupational Loss of Hearing appointed to study the problem. Industry's concern in New York is based upon the fear that this administrative ruling could be withdrawn by the Board at any time, thus resulting in an avalanche of claims which might force many companies out of business.

Workmen's compensation costs in New York, in spite of recent rate reductions, have been among the highest in the country. This is illustrated, for example, by a comparison of workmen's compensation manual insurance rates paid by employers in 35 states, including New York, in the classification of logging and lumbering for the years 1951 through 1954. These figures show that the rates in New York are substantially higher than those in any of the other states. The four-year average for New York is $21.31, whereas the four-year average for all the other 34 states is $8.29 or about 38.5 per cent of the New York rate.

With respect to these high costs, William M. Foss of the New York State Conservation Department has stated (3): ". . . the present compensation law is the greatest single deter-

[1] Presented at Session X, Wood Machining, FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C. A paper on the same subject was presented by Mr. Symons at the Northeast Section Meeting, Oct. 20–21, 1955, in New York City.

[2] Numbers in parentheses refer to notes and references at the end of the paper.

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rent to the proper harvesting of forest products in New York, and to the proper management of our forests for the future."

While the figures given are for logging and lumbering operations, this cost disparity is true generally of most other classifications of operations. It is obvious that to superimpose on this cost structure the added, incalculable burden of awards for occupational loss of hearing would have a serious adverse effect upon the economy of the state.

And what about the effect of this potential on our compensation system in general? In answering this question, I prefer to quote Henry D. Sayer, former Industrial Commissioner and recently retired General Manager of the New York Compensation Insurance Rating Board, who said (4):

> "To my way of thinking the present situation transcends in difficulty any situation that has heretofore arisen in compensation. . . . (The) expense may be of such magnitude as to threaten the continuance of our whole compensation system of free enterprise founded, as it is, on the obligation and ability of industry to pay for its accidents and occupational diseases, passing that cost, as the law requires, along to the ultimate consumer. And it could equally well threaten the compensation systems in those states where free enterprise in compensation is not permitted."

Technical Basis of Industry's Concern

From a technical point of view, industry's concern in New York stems from a concomitance of several factors: 1) the widespread extent of deafness among the general population, 2) the prevalence in industry of noise levels over 90 decibels, 3) the policy in New York of almost automatically treating all noise levels over 90 decibels as injurious *per se,* 4) the presumption contained in the New York law which treats any claim filed as valid unless disproved by the employer by "substantial evidence to the contrary", and 5) the lack of any acceptable damage risk criteria permitting an employer (or its carrier) to overcome this presumption in any case where the employee has worked in a noise level of 90 decibels or over.

If these factors are considered in combination, industry's fears of a staggering potential cost are not without substance.

Extent of Deafness. Dr. Howard P. House, Chairman of the Subcommittee on Noise in Industry of the American Academy of Ophthalmology and Otolaryngology, has stated that one out of every ten persons in this country has some degree of impaired hearing. There are other estimates that range even higher (5). There are many evidences of the extent of this deafness, including the results of hearing tests in elementary schools, the screening of candidates by the U. S. Air Force, and the employment records of plants where audiometric records have been kept. These latter records show that approximately 25 per cent of all job applicants have a significant hearing loss (6).

Prevalence of Industrial Noise Levels of 90 Decibels and Over. In 1953 the Armour Research Foundation of Illinois Institute of Technology made noise studies in a wide variety of industrial operations (7). The study was one of noise levels, both on an over-all intensity basis and analyzed in octave bands, in 580 locations of 40 plants. The measurements were made both at machine levels, within two to five feet from the machine in the vicinity of the operator; and at area levels, where men worked at some distance from the chief source of noise and where several machines generally could be heard.

An analysis of this survey shows that of the 580 locations where the noise was measured, it was 90 decibels and over at 408 locations or at approximately 70.3 per cent of the locations. It was 100 decibels and over at 143 locations or approximately 24.6 per cent of the locations. The conclusion to be drawn from this is that industrial noise levels of 90 decibels and over are far more prevalent than many may have suspected.

Among the industrial operations studied in the Armour Survey was "Lumber and Products" which covered: (a) millwork, (b) the lumber mill of a paper manufacturer, and (c) two furniture plants. In these operations 42 measurements were made, 27 at machine levels and 15 at area levels. Of the machines surveyed, the noise level was 90 decibels or over at 25 of the 27 machines or 92 per cent. Of the 15 area levels surveyed, the noise level was 90 decibels or above at 8 areas or 53 per cent. Of the total 42 measurements made, the noise nevel was 90 decibels or over at 33 locations or 78 per cent of the total locations.

In a footnote to the Armour study it is stated that: "The noisiest machines were found in all industries concerned with metals, followed by the lumber industry." It might also be of interest to point out that the highest noise levels in the lumber and products industry were recorded as:

	Over-all Level in Decibels
Planer, furniture parts	112
Wood planer	108
Cut-off saw (Comp. Air)	107
Circular cut-off saw	106
Surfacer, birch	104
Planer, maple furniture	103
Furniture making, lathes, saws, etc.	103
Sticker moulder	101

In view of these findings, the industrial noise problem in the woodworking field should not be minimized.

Treatment of Noise Levels of 90 Decibels or Over as Injurious Per Se. It is now pretty generally accepted scientifically that the question of the injurious character of noise depends not only on its over-all intensity but on its intensity at the various frequencies in the noise spectrum, the duration of the exposure, and other factors. Nevertheless, the general tendency in New York has been to disregard these other factors and to view any noise level over 90 decibels as injurious regardless of any other considerations.

Presumptions Supporting Claim. This tendency is accentuated by the presumption in the New York Act previously mentioned. Few states have such a drastic doctrine relating to the law of presumptions as New York. Thus in Wisconsin, which has higher benefit levels than New York but where the over-all cost of Workmen's Compensation to employers is less than one-half of the cost to New York employers (8), the employee must prove beyond legitimate doubt that the alleged injury was the result of occupational causes (9).

This difference in the law of presumptions must be taken into consideration in solving the industrial noise problem. In view of the many unknown factors and the multitudinous causes of deafness (even heavy street traffic produces a noise of 95 decibels, a subway train passing a station 100 decibels, etc.), the naked presumption that any industrial noise level of 90 decibels or over is injurious is unjustified.

Lack of Acceptable Criteria to Disprove Claim. The Exploratory Subcommittee of the American Standards Association which recently studied the problem referred to the "obvious gaps in our knowledge" and indicated that it was impossible "to set standards or even to imply that a line can be drawn at the present time between safe and unsafe exposures" (10).

Socio-Economic and Legal Factors

The combination of the foregoing facts lends color to some of the dire predictions of a potential liability beyond industry's capacity to pay unless reasonable limitations and safeguards

are provided. There are also a number of underlying socio-economic and legal reasons why the problem is such a serious one.

Problem of Accrued Liability. In most cases of industrial hearing loss, the condition has been developing over a long period of years during which industry created no reserves to liquidate the claims, and its insurance carriers did not collect any premiums based on the hazard. In the case of "accidents", insurance rates are fixed to cover a *future* liability which may or may not materialize depending on the factor of chance.

"Occupational diseases", on the other hand, are quite different. Not only is the cause often more obscure and complicated by non-occupational factors, but the exposure to harm is generally continuous and uniform so that the percentage or incidence of those who will suffer damage may be far greater, thus affecting the degree of cost to the industry involved. The cost of an accident can generally be determined very easily and thus be charged to the cost of production in the year in which the accident occurs, but this is not true of a *past* liability which has been accumulating slowly over an extended period of time and for which no provision has been made.

This same problem of accrued liability threw thousands of men out of work in New York State in the 1930's when silicosis first became compensable. This was due to the fact that the employers in dusty trades could not obtain insurance coverage at rates which would permit them to operate. This critical situation was not solved until the Legislature enacted emergency legislation drastically limiting the employer's liability for "total disability" by placing it on an escalator (i. e. gradually increasing) basis, and barring awards entirely for "partial disability" (11).

The present problem is more serious than it was in the silicosis situation because industrial noise is far more prevalent than was the silicosis hazard, and the exposure is more difficult to control. We are headed for trouble when, either by legislation or by sudden court rulings, we create obligations stemming from past exposures which, during their existence, were not regarded as creating either legal or economic rights.

Departure from Wage-Loss Concept. Our compensation system grew out of what was equivalent to a compromise between labor and industry under which the employer gave up his defenses of the worker's contributory negligence, the negligence of a fellow servant, and assumption of risk. In place of this old hit-and-miss tort system there was adopted, not a social law, but a substitute legal system of employer's liability based on partial replacement of income lost as a result of any work-connected injury—later expanded to include occupational diseases—regardless of who may have been at fault. It was strictly a legal system of non-fault liability under which a portion of the employee's income loss would be absorbed initially by the employer and then passed on by him to the consuming public.

Without going into the many ramifications of the matter or the reasons for the so-called schedule awards (12), it may be stated that the granting of awards for occupational loss of hearing where there is no loss of income, either present or prospective, vitiates the wage-loss principle on which the compensation system was predicated.

There is a further cogent reason for viewing the departure from this concept with alarm. If we accept the principle of permitting awards for non-economic physiologic and social losses, there is no logical stopping point, either legally or medically. The number of organs in the body that can deteriorate and the number of senses that can become impaired is almost without limit. If we accept the principle, it would be just as logical to grant awards for non-economic psychological, emotional, functional, and psychiatric disabilities claimed to be due to occupation. As Arthur Larson, Under Secretary of Labor, has said: "We must never cut loose from the loss-of-earning capacity concept, for, if we do, there is no telling where the process will stop" (13).

Solution of Problem. To find the right solution will require the whole hearted cooperation of the legislators, state administrative officials, representatives of both labor and industry, and, equally important, doctors, acoustical experts, and safety engineers. All facets of the problem must be considered and intelligently correlated.

Developments in Various States

New York. The requirement of six months' removal from the injurious exposure before any award accounts for the relatively few claims filed to date in New York. Where awards are entered, the percentage loss of hearing is computed on the basis of a medical formula recommended by the Committee of Consultants on Occupational Loss of Hearing.

In 1955 Associated Industries of New York State sponsored a bill to restore the wage-loss principle and to require proof of an actual wage-loss caused by the hearing impairment as a prerequisite to an award. This bill passed the Assembly but was recommitted in the Senate without a vote. Shortly after this the Joint Legislative Committee on Industrial and Labor Conditions (Ostrander Committee) suggested that representatives of industry and labor confer to see if some satisfactory legislative solution of the problem could be agreed upon. This suggestion was accepted and representatives of industry and labor are currently negotiating to see if some mutually satisfactory solution can be worked out.

Wisconsin is the first state which has attempted to solve the problem on a legislative level. It did so by passing a new law in 1955 (14) which provided a modified (i.e. reduced) schedule, the inclusion of the six-month waiting period in the statute for socio-economic reasons, and permitting an employer to deduct pre-existing hearing losses shown by pre-employment examinations.

Wisconsin also has a medical formula, adopted administratively, which differs from the New York formula in that in determining the percentage loss of hearing it: (a) uses only the three frequencies of 500, 1000, and 2000, which are the essential frequencies in the speech range, instead of five frequencies of 250, 500, 1000, 2000, and 4000; (b) eliminates certain minor non-disabling losses (or losses falling within the range of normal variability) entirely; and (c) uses the binaural principle that a man with fairly good hearing in one ear is not as handicapped as a man with pronounced bilateral deafness. Like the New York formula, it provides certain deductions for presbycusis (loss of hearing due to normal aging).

It should be pointed out that the Wisconsin method of dealing with the problem might not necessarily work in other states because of other differences involved, such as the comparative underlying total cost of compensation arising from the general benefit levels and the way in which the laws in the respective states are construed, the fact that in Wisconsin, in addition to the specific percentage deductions in the medical formula for presbycusis, the Wisconsin statute also reduces all awards for permanent partial disability by 2½ per cent for each year that the claimant is over 50 years of age but not to exceed a total of 50 per cent (15), and the possible differences in the law of "presumptions" discussed earlier.

Pennsylvania has recently enacted a law which permits awards for total deafness only.

Missouri has a formula for measuring loss of hearing for compensation purposes (Rule 23) but is currently, through a committee consisting of representatives of industry, labor, and the medical profession, studying the possibility of revising this formula (16).

New Jersey. The Commissioner of Labor and Industry recently assigned one of his Deputy Commissioners to study the problem.

Minnesota. Several claims were recently paid in that state, because to quote from the National Underwriter, "Had hearings been held, they would have established a precedent in the state . . ." (17).

U. S. Department of Labor Model Law. The discussion draft of the model bill is patterned largely after the modified schedule in the Wisconsin law and contains the six-month waiting period. It has no formula for determining the causally related degree or percentage loss of hearing without which no satisfactory solution of the problem can be found.

Importance of Medical Formula

It would be impossible in a paper of this length to discuss in any detail the many questions involved in working out a fair and reasonable medical formula for determining the extent of hearing losses due to industrial noise, the matter of the permanency of the loss, whether the present allowances for presbycusis, as many believe, are inadequate, and other similar questions. While there are differences of opinion as to some of these matters further study will undoubtedly produce the right answers.

Noise Control

The ideal solution for the problem would, of course, be to eliminate the hazard by reducing all industrial noise to safe levels. While this cannot be done overnight due to technical considerations and to the expense involved, many steps are being taken in this direction. American industry is fully aware of its obligation to furnish its employees with the safest possible working environment.

Many references will be found in the recent scientific literature dealing with means of reducing injurious noise levels in industry. This can be done in many ways such as designing and manufacturing less noisy machines, quieting existing machines, isolating noisy operations so that the minimum number of workers will be exposed, etc.

New York Associated Industries has created a Technical Committee on Noise in Industry which has sponsored three state-wide industrial noise conferences dealing with various technical phases of the problem, including practical methods of noise abatement. And while the answers are not clear cut, there are at least some indications that noise abatement produces collateral benefits such as increased production, decrease in absenteeism, decrease in accidents, and improved plant morale. Much remains to be done in this important field.

Plant Conservation of Hearing Programs

In spite of our incomplete technical knowledge, there is much that can be done by individual plants to conserve the hearing of its employees. It is desirable, whenever possible, to make studies of the noise levels in the various operations, and these should be made both on an over-all basis and by a frequency analysis (18). If the employer or its carrier does not have the technicians to make such studies, there are competent consulting engineers and firms available for this purpose, but only qualified experts should be retained because of the many pitfalls involved (19).

These noise studies can be used not only for the purpose of instituting noise control procedures but as a basis of correlating the hearing losses shown by audiometric testing with the noise levels found. The research groups need as much data on these matters as can be developed.

If reasons exist which make it undesirable to give audiometric examinations to all employees exposed to hazardous noise levels, nevertheless it is desirable to make preplacement tests of all newly hired employees. As stated earlier, the available data indicates that 25 per cent of job applicants have a significant hearing loss. Unless such a test is given, the employer will not be able to establish and thereby rule out the pre-existing loss if the employee makes a claim for occupational deafness at some later late.

Such preplacement audiometric examinations can be given by a properly trained technician (20), although if the applicant shows a significant loss he should be referred to an otologist whose testimony would be competent to verify the loss in the event of a subsequent claim.

It is also wise to give newly hired employees who are placed in high noise levels subsequent periodic examinations to ascertain if there are any changes in their hearing acuity that might suggest that they are noise-susceptible individuals. If they are, consideration can be given to transferring them to a less hazardous location.

Another thing which can be done is to furnish ear protection to employees working in high noise levels (21). The use of such protective devices may attenuate the noise reaching the inner ear (where the damage is done to the organ of Corti) by as much as 25 to 30 decibels. In promoting such a program, much educational work will have to be done to overcome the normal reluctance of employees to wear such devices. Caution should also be used to see that they are correctly fitted, worn properly, and kept clean to avoid the danger of any infection.

Research Activities

Much research is now being conducted throughout the country. This covers all phases of the problem, noise control, techniques of noise measurement, predictions of noise susceptibility, evaluation of the permanency of the loss, surveys of the general population to determine the incidence of hearing loss among different groups and categories of individuals, accumulation of data to permit the formulation of acceptable damage risk criteria, and many other matters. Interesting work is also being done in the field of experimental deafness by anesthetizing animals, surgically exposing the auditory cortex, delivering pure tones into the ear canal, and studying the electrical responses. Ultimate correlation of this data will help to bring about the right solution to the problem.

If American ingenuity has been able to master the problem of harnessing atomic energy, it can solve the problem of industrial noise within the framework of our free democratic economy in a way that is fair to all groups, including labor, industry, and the public.

Notes and References

1. The Relations of Hearing Loss to Noise Exposure, report of Exploratory Subcommittee Z 24-X-2 of American Standards Association.
2. Cf. Matter of Slawinski v. J. H. Williams & Co., 298 N. Y. 546; Green Bay Drop Forge Co., et al, v. Industrial Commission and Albert Wojcik, 265 Wisc. 38, 60 N. W. 2d 409; Travelers Insurance Company, Todd Shipyards et al v. Cardillo, 225 F. (2nd) 137
3. Statement made before Moreland Commission, New York City, December 15 1953. At the same hearing Allen W Bratton, Chairman of the Committee on Compensation Insurance of the New York Section of the Society of American Foresters, expressed similar concern about the workmen's compensation problem in connection with forestry and the use of forest products.
4. Sayer, H. D. 1954. The treatment of industrial noise. Best's Insurance News 55 (2): 20–23.
5. It has been estimated that one-fourth of the population has "poorer hearing

than it should have." Volta Review, XXIV, 1922, page 164.
6. Frazier, F. E. 1955. The unsolved factors in loss-of-hearing claims. Paper presented at Third Miami Insurance Law Conference, Miami, Florida, March 29, 1955. Insurance Law Journal, 388: 335–345.
7. Karplus, H. B., and G. Bonvallet. 1953. A noise survey of manufacturing industries. Am. Ind. Hyg. Assoc. Quart. 14: 255–264.
8. For the years 1950 to 1956, inclusive, the average manual rate per $100 of payroll for 45 major occupational classifications was $1.396 in New York as compared to $.689 in Wisconsin. A Pattern for Progress in Workmen's Compensation, Associated Industries of New York State, Inc. 1956.
9. Loomis v. Ind. Commission, 256 N. W. 693; Dentice v. Ind. Commission, 35 N. W. 2d 218.
10. Note 1, supra.
11. Article 4-a of the New York Workmen's Compensation Law. This has since been repealed although compensation is still not payable for "partial disability".
12. For an excellent discussion of some of the general historical background, see Sullivan, J. A.: Legal and Economic Aspects of Noise, Yale University School of Medicine, New Haven, Connecticut, September 17, 1956.
13. Larson, A. 1954. The future of workmen's compensation. Paper presented at the Annual Convention of the International Association of Industrial Accident Boards and Commissions, Chateau Frontenac, Quebec, October 5, 1954.
14. L. 1955, c. 281.
15. Section 102.53, par. 2.
16. Frazier, F. E. 1956. Research, legislation and claims—a discussion of loss of hearing problems. Paper presented at West Coast Noise Symposium, Los Angeles, California.
17. Issue of July 26, 1956.
18. Bonvallet, G. L. 1952. The measurement of industrial noise. Am. Ind. Hyg. Assoc. Quart. 13: 137–157; Handbook of noise measurement, General Radio Corporation, Cambridge, Mass.
19. Williams, C. R. and J. R. Cox, Jr. 1952. Industrial noise measurement—science or art? Proceedings of Third National Noise Abatement Symposium, Chicago, Ill. Vol. 3: pp. 1–18.
20. More and more colleges are conducting short term courses for the training of technicians, including Colby College, Marquette University, and others.
21. Wheeler, D. E. 1953. Ear protection in industrial noise exposure. Am. Ind. Hyg. Assoc. Quart. 14: 1; March, 1953; Wheeler, D. E. and A. Glorig. 1955. The industrial hygienist and ear protection. Am. Ind. Hyg. Assoc. Quart. 16:1.

Discussion

S. H. Wise (Wood Conversion Co.): What frequency ranges should be measured to determine the noise level?

Mr. Symons: All the octave bands starting with the 20 to 75 and including the 4800 to 10,000 cycle per second bands should be measured. Otherwise there is no basis for determining the actual spectrum of the noise involved.

Mr. Wise: What frequency range is felt to be the most injurious?

Mr. Symons: Concerning the frequencies felt to be the most injurious we have another problem. There is as yet no consensus among the medical people on this point. There have in the past been numerous published statements to the effect that the first noise induced hearing loss appears at about one-half to one octave above the frequency of the sound responsible for the damage. Since hearing losses supposedly due to noise usually appear first at around the 4000 cycle frequency, this would indicate that sound in the frequency 1200 to 2400 cycles per second might be the most important. As a result of recent studies by research groups, however, the opinion has been expressed that noises in the 300 to 600 and 600 to 1200 cycle frequencies are probably the most important. I have not seen the data upon which this opinion is based. Summing this up, it would appear that the general trend of medical opinion at present concerning the most important frequencies would range from 300 to 2400 cycles per second. Much research remains to be done before any definite conclusions can be presented.

Whole Tree Harvesting[1]

R. C. SPROULL, R. B. PARKER, and W. L. BELVIN

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The general economics of utilizing the whole tree, including roots, bark, limbs, and twigs, are discussed. Differences in fiber dimensions and wood structure of various sections of the tree are related to properties of paper made from these sections. Potential uses for various portions of the tree are reviewed.

A NEW CONCEPT in forest management as related to utilization is presented in this paper. This concept is much too broad in scope to be adequately covered in a single publication. Essentially it is an idea which encompasses the whole field of wood utilization.

The authors have been advised by a confidential communication that a group of economists have also concluded that whole tree harvesting offers the best opportunity to increase the values from American forests.

Whole tree harvesting means collecting all the tree which can be readily salvaged, including roots, bark, limbs, and some twigs. The concept begins with selection of equipment for up-rooting trees and ends with preparation of the land for the next crop of seedlings. It differs from the term "whole tree logging" in that the stump is claimed. Its primary purpose is to salvage *all* parts of the tree for profitable use.

The principal reason for this paper is to stimulate integrated thinking and to present an idea, with examples, which can ultimately add many new

[1] Presented at Session VIII, Chemical Utilization, FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

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values to our forests. The only reference directly pertinent to this idea is the bulletin entitled "Full-Tree Logging—A Challenge to Research" by A. Koroleff and published by the Pulp and Paper Research Institute of Canada, 3420 University Street, Montreal 2, Canada.

Importance

Dr. Locke, in his review of Chemical Utilization,[2] illustrates adequately the reasons for increasing forest yields. Briefly summarized these are: increasing population; growth of the fiber-using industries, especially pulp and paper; development of new chemical and pulp products, and an ever-increasing world demand for fiber products as the economy of retarded countries improves.

Equipment Required

A question readily answered is whether equipment is available for harvesting the whole tree. The answer is yes, if it is adapted to salvage special portions of the tree. Land clearing equipment is available for rapid felling of trees of all sizes. For recovery of the stumps, the practices of the naval stores industry can be followed. The well-established procedures of the lumber and paper industries can be followed to claim the remainder of the tree. Bark removal can be accomplished readily in the forest or in the processing plant. Companies can supply debarkers for a wide variety of applications.

When the concept of whole tree harvesting is fully perfected, the use of equipment for tree toppling, logging, dirt removal, chipping, conveying, and land preparation will be coordinated to deliver only usable materials to the processing plant.

Properties of Different Portions of Southern Pine Trees

The amount of pulpwood which could be salvaged from land clearing in progress annually in the United States is estimated to be about one million cords. This, in itself, would be a good reason to explore the use of the whole tree for fiber products.

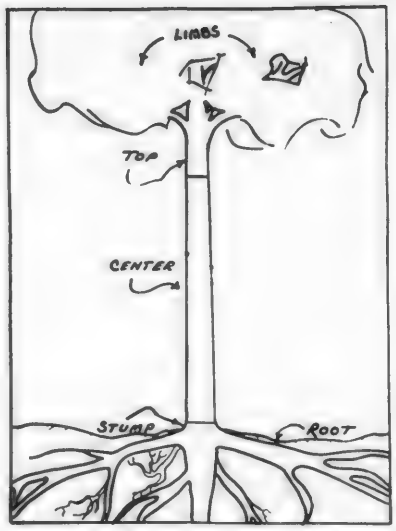

Fig. 1.—Sampling plan.

The trees used in this study were growing about 25 miles north of Savannah, Georgia. Less than 30 seconds were required to uproot each tree with a heavy-duty tractor.

The body of each tree was sawed into 4-foot lengths and carried to the laboratory along with the roots, stump, branches, and twigs. The trees were divided into five sections as shown in Fig. 1. The *stump* was the part four inches above ground and included the tap root which adhered to the stump. The *base* was the lower four feet of the trunk. The *top* was the upper eight feet of the trunk. The remainder was classed as *center*. The center was sometimes divided into base and trunk.

Each stick was carefully weighed and a disc cut from its center. After weighing these discs, and removing the bark, the wood section was submerged in water and displacement measured in milliliters. From these samples the per cent moisture, per cent wood, per cent bark, and age were determined.

Wood Properties

Table 1 shows the age, growth rate, and wood yield information on three trees of about average pulpwood size. The yield is calculated with the total weight of the wood substance as 100 per cent. The wood of greatest density, as expected, was in the center section and that of lowest density was in the stump. The stump wood was visibly different than that from other portions of the tree; it was "cork-like".

The sticks were weighed before and after bark removal to correct for moisture variations during the work. About 60 per cent of the wood substance is in the body of the tree. This portion might be considered current pulpwood size.

Table 2 presents some values for the distribution of wood and bark in the different portions of the tree. These are incomplete, but are a qualitative indication that the greatest amount of bark is in the limbs and roots.

About 15 to 18 per cent bark may be expected from the composite tree for southern pine trees of this size. This value will vary widely with tree size, species, and conditions of growth.

These data, though incomplete, suggest that if the entire tree is to be harvested, additional values of 30–40 per cent might be derived from the currently unused portions of the tree. The percentage of useful products can be further increased, when a use for the bark is available. Cone[3] describes some areas of use for bark. These need to be further developed.

Pulping Properties

A. Chipping: Two-foot lengths from each section of one tree were chipped in the Carthage chipper. The chips from each section varied in shape and size. The chips were classified on a Syntron classifier with round and square holes for 20 minutes shaking. Results are shown in Table 3.

The data readily suggest that the yield of most desirable chips would be obtained from the center, followed in order by the top, limbs, stump, and roots. This does not tell the whole story. The stump and root chips contained many wafer pieces, some as large as a saucer. Means for producing more uniform chips from the stump would have to be developed.

[2] Locke, E. G. 1956. Review of chemical utilization. For. Prod. Jour. VI (2): 63–66.

[3] Cone, C. D., Jr. 1956. A brief survey of bark utilization. Southern Pulp and Paper Manufacturer. 19 (4) 92–94.

Table 1.—AGE, GROWTH RATE AND WOOD YIELD

	Pine 1	Pine 3	Pine 4	Calculated Mean
Age, yr.	41	17	17	25
Variety	Longleaf	Slash	Slash	
Diameter, in.	8.25	8.25	8.50	8.33
Growth diam. in/yr.	0.201	0.485	0.500	0.395
	Yield, Per cent of total tree weight			
Middle	60.0 (12.5)*	39.4	45.5	48.3
Base	9.7	17.9	10.6	12.7
Top	4.8 (11.2)	4.2	3.7	4.2
Stump	16.7 (6.9)	16.8	20.2	17.9
Root	2.0 (9.9)	4.6	4.5	3.7
Limbs, and twigs	6.7† (9.6)	17.1	15.7	13.2

*Figures in parenthesis are oven dried densities/lb. per cu. ft.
†Without twigs and needles.

Table 2.—BARK AND WOOD CONTENT

	Per Cent					
	Pine 1		Pine 3		Pine	
Section	Wood	Bark	Wood	Bark	Wood	Bark
Middle	86.25	13.75	83	17	91	
Base	88.6	11.4	88	12	90	
Top	76.2	23.8	81	19	67	
Stump	86.5	13.5				
Root	69.3	30.7				
Limbs	60.0	40.0				
Composite*	83.8	16.2				

*Weighted.

Table 3.—CHIP SIZE CLASSIFICATION

Section	Rating	Per Cent Retained On ¾" Square-Round	¼" Square-Round	In Pan Square-Round
Center	1	0 1.3	73.4 88.0	26.6 10.7
Stump	4	43.4 65.9	56.1 33.6	1.3 0.5
Top	2	3.1 7.8	83.0 84.5	14.1 7.8
Limbs	3	10.9 5.0	79.8 77.1	9.3 17.9
Roots	5	75.2 62.0	22.4 34.3	2.1 3.65

Table 4.—COOKING DATA

A. HIGH YIELD

Identification	Stump	Center	Top	Limb	Root
Cook	2WP	1WP	3WP	4WP	5WP
Air dr. chips, g.	3619	3540	4124	2611	2516
Moisture in chips, %	44.7	43.5	51.5	23.4	20.5
Moisture in chips, g.	1619	1540	2124	611	516
Total alkali, g/1 Na_2O	29.8	32.9	34.6	26.0	33.5
Active alkali, g/1 Na_2O	21.7	21.4	23.6	21.0	27.9
Active alkali, %	17.4	17.1	18.8	16.9	22.2
Sulfid. , %	33.4	30.2	28.6	42.8	22.0
Time conditions, min.	75	90	90	90	75
Time conditions, hr.	2	2	2	2	2
Tem. range °C	161—168	160—166	161—174	160—175	160—175
Yield, %	65	66	63	63	45

Table 7.—PHYSICAL PROPERTIES—SUMMATION

Section	Burst Factor		Tear Factor		Average	
Freeness	400	500	400	500	400	500
Center	88	76	258	278	173	177
Stump	161	157	152	166	156	161
Top	126	122	200	214	163	168
Limb	108	106	132	144	120	125
Roots	148	141	169	187	159	164

Table 6.—HANDSHEET EVALUATION

A. HIGH YIELD

500 Freeness—3 gm Canadian Standard

Pulp from Cook No.	Time Min.	Burst Factor	Tear Factor	Tensile Bk. Lgt. in Yds.
1WP Center	63	76	278	6420
2WP Stump	77	157	166	10400
3WP Top	62	122	214	8860
4WP Limb	59	106	144	8210
5WP Root	56	141	187	10290
400 Freeness				
1WP	76	88	258	6810
2WP	89	161	152	10700
3WP	75	126	200	9100
4WP	70	108	132	8510
5WP	67	148	169	10420

B. MEDIUM YIELD

500 Freeness—3 grams Canadian Standard

Position	Pulp from Cook No.	Time Min.	Burst Factor	Tear Factor	Tensile Bk. Lgt. Yds.
Base Core	1	44	110	268	7450
Base Middle	2	68	127	270	7600
Base Slab	3	61	115	284	7000
Middle Middle	4	35	112	272	8100
Top Composite	5	27	136	245	8500
Middle Slab	6	39	119	390	7620
Middle Core	7	49	130	222	8450
400 Freeness					
	1	53	119	258	7900
	2	80	140	248	8100
	3	75	128	250	7800
	4	43	120	254	8700
	5	32	142	238	9270
	6	46	217	360	7900
	7	58	138	202	9000
300 Freeness					
	1	62	124	240	8200
	2	93	139	230	8200
	3	86	135	236	7950
	4	50	125	238	9000
	5	38	144	230	9600
	6	54	132	327	8010
	7	66	142	187	9300

B. Pulping: The kraft method of pulping was selected because of known favorable results already available from pine. First conditions used gave high yields. A stationary digester of about 5-gallon capacity was employed. It was heated indirectly and the liquor circulated through the chips. The liquor to chip ratio was 8:1, the total volume of liquor per cook was 16,000 ml with 2000 grams (O. D.) chips, other conditions are shown in Table 4.

Another set of cooks was made to observe differences from the outer or slab portion of the log to the center of the log. This was done in a 1 cubic foot, stainless steel rotary digester. Three portions were taken at three positions along the tree. These results would be nearly comparable to kraft pulp mill practices in the South. Conditions are also shown in Table 5 under medium yield (B).

C. Pulp Evaluation: Pulp from the pine kraft cooks was evaluated by beating in a Valley beater of 1½ pound capacity, with handsheets and freeness determinations made at suitable intervals.

The handsheets were conditioned overnight. Thickness, burst, tensile, tear, and basis weight measurements were made on the handsheets. The most pertinent results are shown in Table 6. Several freeness values are used to illustrate the results which might be expected for the pulp after three levels of beating.

Table 7 summarizes these data for burst and tear of high yield pulps with the average at the two freenesses. The center section gave the highest tear and lowest burst, whereas the stump gave the highest burst and an intermediate tear.

The physical properties of the medium yield pulps, 1–7, from different positions along the trunk and with respect to diameter were similar. The slab section showed higher tear and lower burst, whereas the top showed somewhat higher burst and lower tear.

Without examining the data in detail, it is easy to conclude that sections of the tree might be selected to accentuate a particular property desired in the paper.

All samples of paper were of good quality.

D. Fiber Dimensions: A 10-gram sample of pulp was dispersed in distilled water in a 500 ml Erlenmeyer flask. By decantation and dilution with water, the fiber content was reduced to a very low consistency. A portion was placed in test tubes and shaken before pouring.

A little of the suspension was removed by a 5 ml. pipette, after standing for approximately one hour. The inside diameter of the pipette was 5 mm. A drop was placed on each of eight slides. The fiber suspension was stained with 1 per cent Congo red. These were dried on a hot plate. The slides were placed on the Projektina, aligned, and the length of each fiber measured to the nearest 0.1 mm.

The slides were transferred to the microscope and, with a magnification of 450, the diameters of the fibers were measured to the nearest 0.001 mm. The total range of fiber lengths and widths are summarized in Table 8. The longest individual fibers were in the center and the shortest in the limbs although the stump averaged the longest. The length of fibers from other sections was intermediate. These fiber

Table 5.—COOKING DATA

B. MEDIUM YIELD

Identification in the tree	1 Base core	2 Base middle	3 Base slab	4 Middle middle	5 Top composite	6 Middle slab	7 Middle core
O.D. Chips (gms)	3753	3753	3753	3753	3753	3753	2511
A.D. Chips (gms)	6024	6685	6538	6224	7442	6361	4083
Moisture in Chips (gms)	2371	2932	2785	2511	3689	2608	1572
Moisture in Chips (%)	37.7	43.8	42.3	39.7	49.6	41.0	38.5
Liquor Added (ml)	19,256	19,256	19,256	19,556	19,556	19,556	8187
Total Volume (ml)	21,627	22,188	22,041	22,067	23,245	22,165	9795
Ratio	5.7:1	6.0:1	5.9:1	5.8:1	6.0:1	5.9:1	3.9:1
Total Alkali (g/1 Na_2O)	49.6	49.6	49.6	49.6	49.6	49.6	49.6
Active Alkali (g/1 Na_2O)	39.0	39.0	39.0	39.0	38.4	38.4	38.4
Active Alkali (%)	20	20	20	20	20	20	12.5
Time to Conditions (minutes)	135	150	210	120	180	150	90
Time at Conditions (minutes)	90	90	90	90	90	90	90
Temperature range (degrees C)	170 174	166 176	170 174	170 174	169 172	170 175	165 177
Yield Unscreened (%)	46	47	49	------	38	48	50

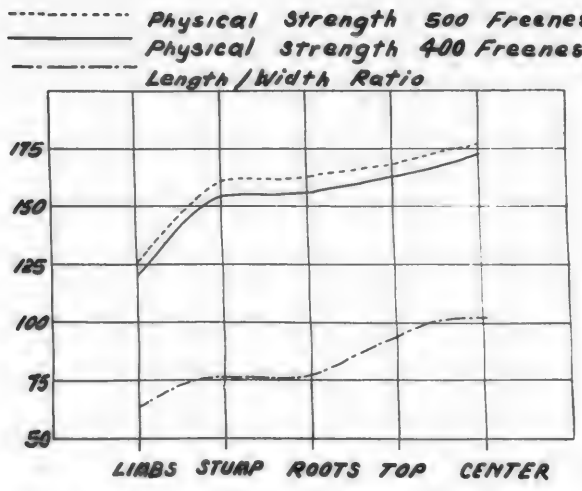

Fig. 2.—Relation of strength and fiber length to width ratio.

dimension data were published by Gleaton and Saydah.[4]

E. Relationship of Fiber Dimensions and Strength: The ratio of length to width of the fiber has a direct relationship to the over-all strength of the pulp. The per cent Mullen and per cent tear were added together and divided by two to give an average empirical strength value. Figure 2 shows that the strength varies almost directly with the fiber length to width ratio.

Analyses of Experimental Data

The information reported was gained from a limited number of samples. The results suggest that a much greater number of samples be selected statistically from a much greater number of trees and evaluated for optimum applications.

Conclusions

The following general conclusions can be drawn:

1. It is possible to make a good quality pulp from each section of the tree.

2. Good yields, on a weight basis, may be expected from each section of the tree when optimum cooking conditions are established.

3. Chips from the middle and top sections have greater uniformity. Chips from the stump section were "puffy" and uneven in size. Different chipping conditions are needed to yield best quality chips from the stump, roots, and limbs.

4. Pulp yield was lowest, by the method employed, from the smallest or youngest sections of the tree (i.e. roots, limbs).

5. The stump section contained the longest fibers and gave the strongest Mullen.

6. A direct relation between the length to width ratio of the fibers and strength of handsheets made from the pulps was found.

Economics

Based on the preliminary data reported and other supporting information, not included, the following general economics apply to whole tree harvesting:

1. The yield of pulp from the forest could be increased 30–40 per cent.

2. The market value of the products derivable from the additional pulp, if converted to the same value as wood pulp now in use, would be in the range of $2 billion to $3 billion annually.

3. The removal of organic debris from the forest would reduce fire hazards and cut down on the cost of fire protection.

4. The land would be prepared for replanting of seedlings or natural reforestation by use of suitable land preparation equipment after tree harvesting.

5. A cost reduction would result from reduced wood handling costs at the pulp mill by maintaining a steady flow of chips from the forest to the pulp mill.

As the field is developed other advantages would become apparent. The stakes are so large that the task merits the best application abilities of the land owner, the forester, the scientist, the economist, the engineer, the salesman, and the corporate investor.

[4] Gleaton, Earl and Lenora Saydah. 1956. Tappi 39 (2): 157A.

Table 8.—FIBER DIMENSIONS

		Length, mm			Width, mm			
	Cook No.	Max.	Min.	Average	Max.	Min.	Average	Ratio
Center	2WP	6.2	0.4	2.76	0.048	0.15	0.026	106.1
Stump	2WP	5.4	0.5	2.93	0.052	0.019	0.038	77.1
Top	3WP	5.3	0.4	2.52	0.049	0.010	0.028	90.0
Limbs	4WP	3.4	0.4	1.72	0.042	0.010	0.027	63.8
Roots	5WP	5.4	0.3	2.50	0.048	0.014	0.032	78.3
Composite	6L	5.6	0.3	2.53	0.048	0.012	0.029	87.7

Discussion

E. P. Ivory (Ivory Pine Co.): What method is used in cutting up, loading, transporting, and handling the materials from the five parts of the tree?

Dr. Sproull: This hasn't been worked out as yet. Many known methods for specialized phases can be put together to arrive at an economical solution.

A. S. Gregory (Weyerhaeuser Timber Co.): What barking equipment is available for handling the limbs and roots?

Dr. Sproull: There is none available for complete bark removal. One could bark part of the roots and limbs in the woods, then digest the chips with the remainder of bark. After digestion, the bark can be removed from the pulp by cleaning devices as the pulp slurry progresses through the papermaking process.

W. L. Meek (Minnesota and Ontario Paper Co.): We have had some experience with centrifugal cleaners as a means of removing bark from pulp and find they do a reasonably good job.

G. E. Bell (Forest Products Lab of Canada): What was used as a standard for pulp chips in the comparison of the chips from the various parts of the tree?

Dr. Sproull: Standards set by a paper company in the manufacture of their commercial pulp were used. Chips were screened through ¾ and/or ¼ inch mesh. Uniform chips allow maximum digestor capacity.

L. E. Miller (Holly Hill Lumber Co.): Does the rind of the log, i.e., slab wood and edgings, give a better yield of pulp than small, round wood?

Dr. Sproull: The outside of the tree is known to give slightly better pulp.

L. C. Wallace (Crown Cork and Seal Co.): Compared with standard practice, what is the relative consumption of pulping chemicals in cooking those portions of tree not usually harvested—particularly in the presence of relatively large quantities of dirt and bark?

Dr. Sproull: Consumption is somewhat higher for those portions which give lower pulp yield, but if a process such as the kraft is used, these chemicals are in the main recoverable

Douglas-Fir Bark as a Source of Quercetin[1]

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A low-cost oxidation process has been developed which converts dihydroquercetin present in the water extract of Douglas-fir bark to quercetin. This product is much less soluble and readily recovered. The effects of the independent process variables on the reaction, and possible reaction mechanism are discussed.

Introduction and Review of Previous Work

MILLIONS OF TONS of Douglas-fir bark are available annually as a by-product of the lumbering and pulping industries in the Pacific Northwest. One company is making limited utilization of this material in the form of its mechanical fractions, but the major percentage of the bark is being burned as fuel. During the past ten years, there has been an increase in research and development activities to chemically utilize this raw material.

The chemical composition of Douglas-fir bark is very complex and not fully known. Furthermore, it varies with the history of the sample. A general expression of composition is given in Table 1 for commercially available hydraulic barker waste. Other analysis of selected bark samples can be found in the literature(1)[2].

Each of the extractive fractions is a mixture of chemicals. The ether solubles obtained using the solvent sequence noted in Table 1 are relatively simple and consist predominantly of an organic chemical known as dihydroquercetin (3, 3′, 4′, 5, 7-pentahydroxy-flavanone) belonging to the flavonoid family. The first published information on the presence of this compound in Douglas-fir wood was by Pew(2). The structures of this flavanone and the closely related flavone, quercetin, are given in Fig. 1.

Quercetin and certain of its derivatives are widespread in plants; for example, it occurs in hops, tea, horse chestnuts, red roses, buckwheat, and in the inner bark of the North American black oak. A limited quantity of quercetin has been commercially extracted from the latter source and used as a dye for wool and other fibers. The glycoside of quercetin, rutin, has been extracted for pharmaceutical uses. However, quercetin has not been available as a pure chemical in large volume, and markets for large volumes are not established.

DHQ is quite soluble in hot water (13.5% at 100° C.) and relatively insoluble in cold water (0.25% at 25° C.). Thus, hot water extraction followed by cooling and crystallization appeared to be an attractive method for DHQ production. Techniques were developed for countercurrent extraction of the bark to produce an extract containing approximately 3% soluble solids.

The composition of solids in such an extract from whole Douglas-fir

[1] Presented at Session VIII, Chemical Utilization, FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

[2] Numbers in parentheses refer to literature cited.

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L. E. Dowd holds B. S. from U. of Washington, joined the Pulp Division or Weyerhaeuser in 1941. He was transferred to the Technical Center in 1943, where he is a Development Scientist.

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Table 1.—COMPOSITION OF A SAMPLE OF DOUGLAS-FIR BARK (FROM HYDRAULIC BARKER)

Extractives (Sequential)	Yield %*	General Nature of Material
Hexane	4.0	Light Colored "Wax"
Benzene	2.3	Dark Colored "Wax"
Ether	3.3	Dihydroquercetin (75% Purity)
Water	9.9	Tannins and Carbohydrates
Ethanol	3.4	Phlobaphenes
Solubles—Aqueous Sodium Hydroxide (100° C.)	37.6	Phenolic Acids, Other Saponification Products
Total Extractives Plus Solubles	60.5	
Residue	39.5	"Lignocellulose"
Total	100.0	

* Basis of weight of O.D. Douglas-fir bark.

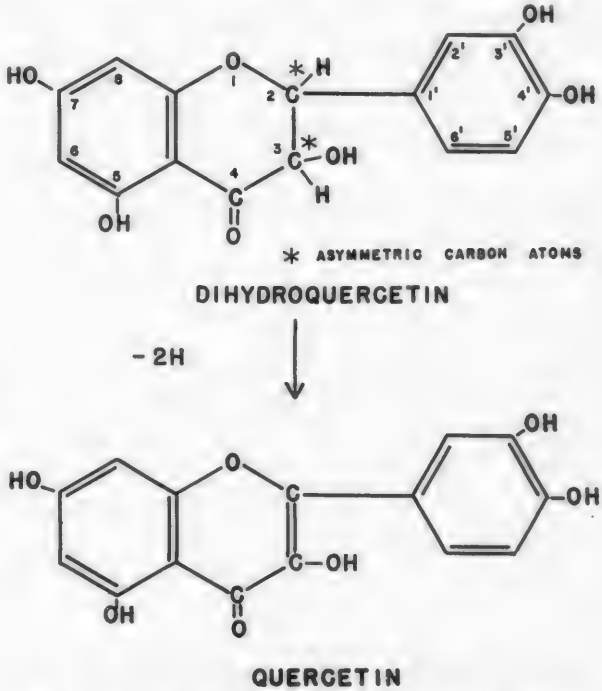

Fig. 1.—Chemical structure of dihydroquercetin and quercetin.

bark available at commercial hydraulic barkers is given in Table 2. The DHQ in this sample was 18% of the solubles. Thus, the extract at 3% soluble solids contained 0.54% DHQ. Even though such a concentration exceeds the cold water solubility of DHQ, it is very difficult to crystallize. The dispersing or crystallization inhibiting powers of the non-DHQ materials present is marked. Yields and purity of DHQ obtained by direct crystallization were low, even though the extract was concentrated to levels greatly exceeding the solubility of DHQ in pure water.

Further demonstration of this crystallization inhibiting effect has been shown by the addition of small amounts of the non-DHQ extract solubles to pure aqueous solutions of DHQ. Several methods have been worked out for the removal of DHQ from this water extract or directly from the bark, but each has economic limitations.

Table 2.—COMPOSITION OF A HOT WATER EXTRACT FROM DOUGLAS-FIR BARK

	Solubles %*
Hexane Solubles	1
Benzene Solubles	4
Ether Solubles (75% DHQ)	24
Remaining Water Solubles:	
Tannins†	41
Non-Tannins	30
Total	100

*Basis of solids in extract.
†Exclusive of tannin content of ether solubles.

Since Q is far less soluble than DHQ in water (0.1% at 100° C. and less than .002% at 25° C.) and is more easily crystallized, the conversion of DHQ to Q in the water extract has been explored. It was desirable to find a process that: (a) could be carried out in simple equipment, (b) used small amounts of low cost reagents, (c) operated on extracts of varying concentration and composition, (d) had a minimum effect on the other components of the extract (degradation or contamination), (e) was capable of completion in a short period of time, and (f) gave good yields and high product purity. The method reported here appears to meet these requirements.

The various laboratory methods that have been published for oxidizing flavanones to flavones are listed in Table 3. As described, none of these was considered suitable for carrying out the conversion in the presence of large proportions of "tannin-like" materials on a commercial basis. The possibility existed, however, of finding conditions for a satisfactory air oxidation.

The acid conditions used by Pew(2) precipitated large quantities of phlobaphene which reduced the tannin content of the balance of the extract and contaminated the insoluble Q. In addition, the quantity of acid required was high. On the other hand, strongly alkaline conditions led to degradation as has been shown for other 3 hydroxy-

Table 3.—METHODS OF FLAVANONE–FLAVONE CONVERSION

	Method	Approximate Yield, %	Lit. Cited No.
(A)	Catalytic Dehydrogenation using a Catalyst (Pd-Charcoal) and a Hydrogen Acceptor	16	(3,4)
(B)	Oxidation with Alkaline Peroxide	50	(6)
(C)	Oxidation with Air in Aqueous Alkali (Generally Strong Alkali)	10–20	(5,6)
(D)	Disporportionation using Alcoholic Base in the Presence of Air	28	(7)
(E)	Oxidation with Bismuth Acetate and Basic Bismuth Carbonate	75	(8)
(F)	Oxidation with Air in Sulfuric Acid	75	(2)
(G)	Iodine Oxidation	60	(9)
(H)	Sodium Bisulfite	90	(10)
(I)	Isolation of Ammonium Salt followed by Prolonged Refluxing	64	(18)

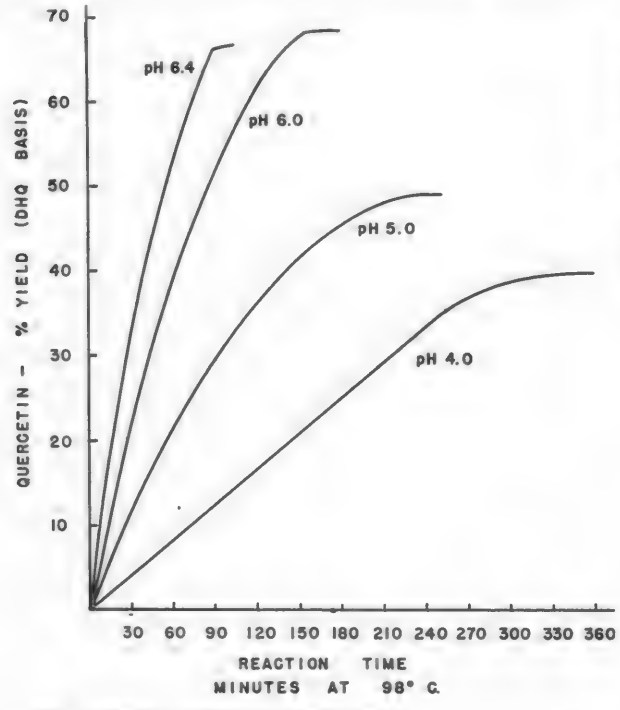

Fig. 2.—Effect of acidity on oxidation rate.

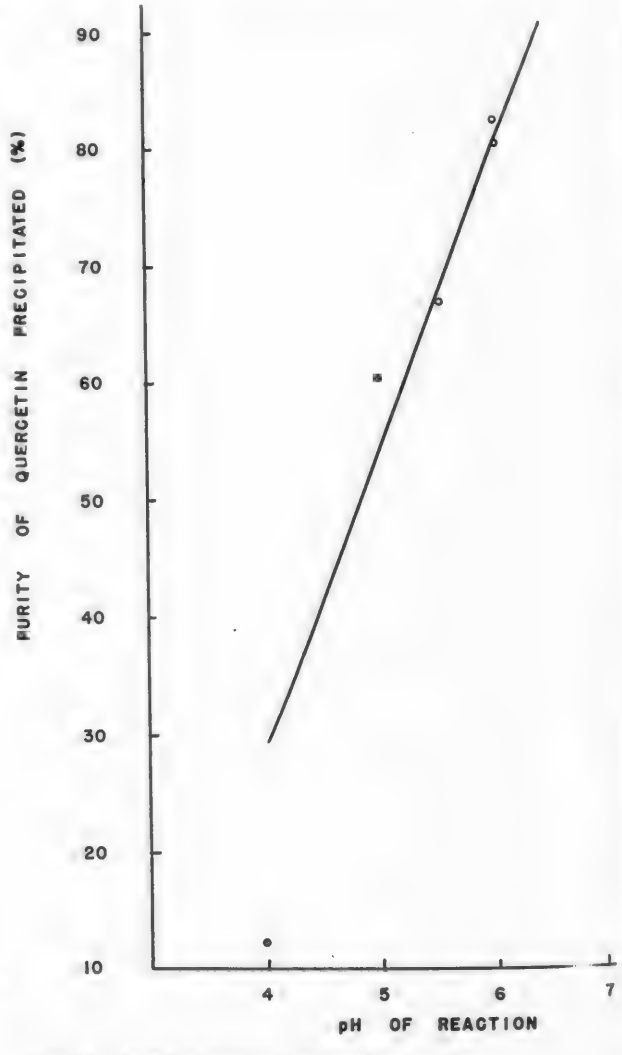

Fig. 3.—Purity of quercetin recovered vs. acidity.

flav nones which go initially to the α-diketone and then to simple phenols(11) or rearrange to the isomeric ben lcoumaranone(12).

Experimental Procedure

tensive laboratory and pilot plant stu es were carried out in which the effe s on yield, purity, and reaction rate produced by changes in the variabl listed below were explored.

1. Hydrogen ion concentration.
2. Type of alkali used to adjust hydrogen ion concentration.
3. Temperature of reaction.
4. Oxygen concentration and aeration rate.
5. Degree of agitation.
6. Use of catalysts.
7. Concentration of extract.
8. Extract composition.

Other experiments were carried out to gain insight into reaction mechanism and competing reactions.

Several analytical techniques were used. Progress of reaction was readily followed using a method based on ultra-violet absorption. Q was determined by measuring the difference in absorption at 3750Å of a sample (diluted in ethanol-water) of the reaction mixture before and after removal of the insoluble Q by centrifugation. DHQ was calculated from the absorption spectra of a basic solution of the mother liquor, using two wave-length measurements and solving by simultaneous equations.

Another procedure that would be applicable has been described by Maranville and Goldschmid(13). Gravimetric analyses were used to measure final yields of Q as well as initial and final concentrations of DHQ. The latter involved a bisulfite conversion of DHQ to Q by a modification of the technique reported by Kurth(10).

The experimental results are summarized in the following paragraphs:

(a) Effect of acidity and reagents used for its adjustment: The normal pH of water extract of Douglas-fir bark is approximately 3.4. The pH of the system was adjusted to several values up to pH 8 by addition of alkaline reacting materials including: sodium hydroxide, ammonium hydroxide, sodium acetate, sodium phosphate, and sodium sulfite. Mixtures of alkaline materials were also used. Since yields were in the same range for each type of alkali, the amount required to adjust pH to a given value and price per pound made sodium hydroxide appear most economical.

The rate of formation and yield of precipitated Q generally increased with an increase in pH to an optimum for a given temperature. At 95°–100° C., this pH was in the range of 6 to 6.5 (Fig. 2). At pH's above 7, yields were decreased because of competing reactions. Under conditions selected for preparation and air oxidation of water extract, purity of product increased with pH (Fig. 3) largely because of the solubilizing effect on materials other than DHQ present in the extract. The pH given is the pH of reaction mixture at 25° C.; at reaction temperature systems would be more acidic.

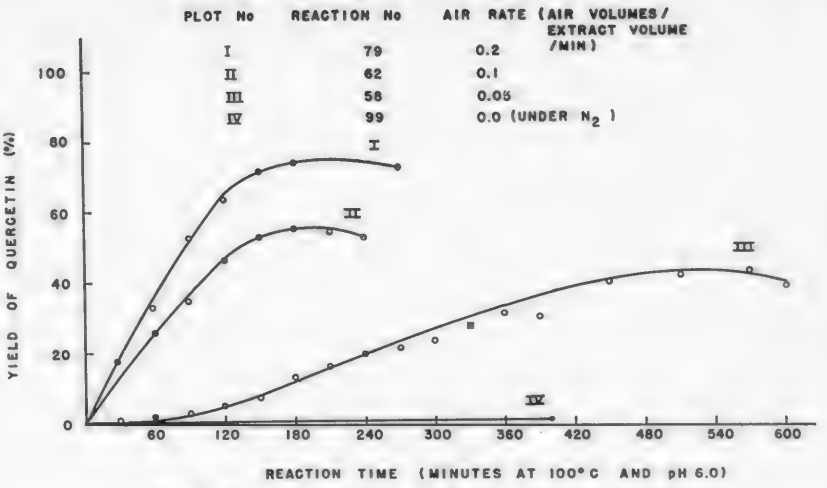
PLOT No
REACTION No
AIR RATE (AIR VOLUMES/ EXTRACT VOLUME /MIN)
I 79 0.2
II 62 0.1
III 58 0.05
IV 99 0.0 (UNDER N_2)
YIELD OF QUERCETIN (%)
REACTION TIME (MINUTES AT 100° C AND pH 6.0)

Fig. 4—Dependence of rate of Q formation on air rate.

(b) Temperature of reaction and oxygen concentration: Increase in temperature has several effects upon the oxidation. It not only accelerates the reactions taking place but at the same time reduces the solubility of oxygen in the aqueous media. It also increases the solubility of Q in the reaction mixture so that more is available for degradation per unit of time. There appears to be an optimum oxygen concentration for maximum yield and reaction rate at each temperature.

Air requirements for reactions at 95°, 63°, and 25° C. were studied. Under the experimental conditions used, it was found that 0.2 volumes of air per minute per volume of 3% extract produced an aeration that gave maximum reaction rate at 95° C. or higher. Yields in the range of 70% were obtained within 1½ to 3 hours, depending upon extract used (Fig. 4). Since the solubility of oxygen in water, and presumably extract, at these temperatures is very low, it imposes a limit on oxygen concentration. Increasing air rates above 0.2 volumes per minute per volume 3% extract had only slightly detrimental effects.

As temperature of reaction is lowered, oxygen solubility increases, and at 63° C. 0.05 volumes of air per minute per volume 3% extract were found adequate to give 70% yields in 24 hours. At 25° C., the amount of air admitted to the reaction had to be very carefully limited or excessively low yields were obtained. Completion of reaction at this temperature required 10–14 days.

Preliminary work has indicated that slight increases in pressure improve yield and reaction rate. Future work will indicate the extent of any advantages to be gained.

(c) Degree of agitation and use of catalysts: Complete and uniform mixing assists in control of the reaction. At the higher temperatures where oxygen solubility was reduced, a high degree of stirring became advantageous to keep the reaction mixture saturated with oxygen and possibly to permit maximum oxidation at bubble interfaces.

Several of the common metal oxides used to catalyze autoxidations and peroxide reagents were screened for catalytic effect on this reaction. Although initial results were not encouraging, further study will show whether their use is justified.

(d) Concentration of extract: Most of the work in this study was conducted with extracts of approximately 3% concentration and with composition similar to that described in Table 2. This material was used because it could be directly produced commercially and because early work showed that concentrating the extract to higher levels was of little advantage. In early work, extract solids concentrations from 1% to 35% were briefly explored. At concentrations below 3%, conversion of DHQ to Q was good. However, yield of Q which could be removed by filtration was low due to a greater percentage loss resulting from Q solubility. This solubility has been found to be 0.026 grams of Q per 100 grams of reaction mixture at 25° C. As the concentration of the extract was increased above 3%, the purity of Q which separated

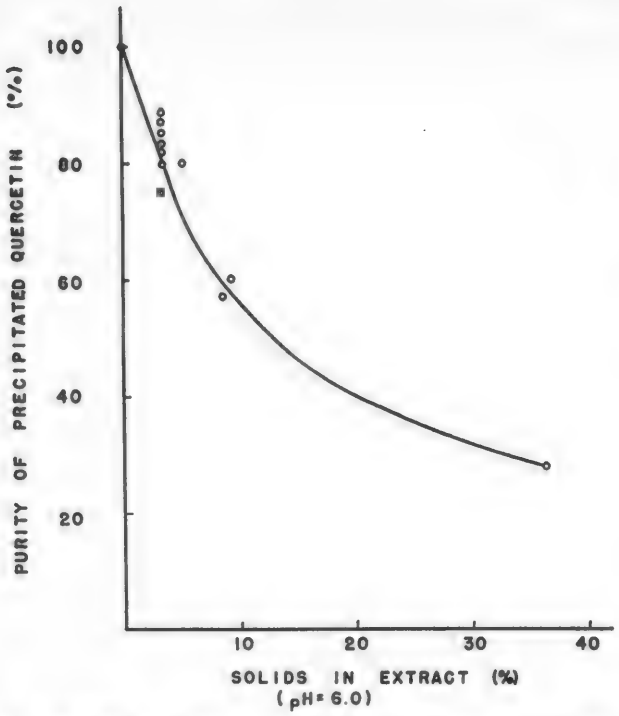

Fig. 5.—Effect of concentration on purity of precipitated quercetin.

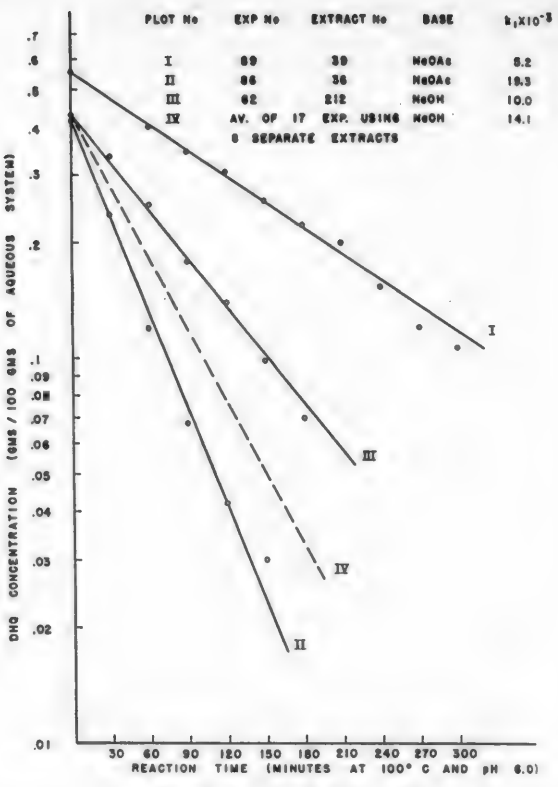

Fig. 6—Rate of DHQ disappearance.

from the cooled reaction mixture decreased due to the presence of other materials insoluble at these concentrations (Fig. 5).

(e) Extract composition: The composition of Douglas-fir barker waste as obtained at a mill site varies from log to log depending on age of the tree, portion of the tree, length of time since tree was felled, duration of log pond storage, and handling of bark after removal from the log. The effect of some of these variables on extractives content, especially DHQ, has been discussed in the literature(1).

The composition of the water extract varies with the raw material, and these changes in composition affect the rate of Q formation and, to a lesser degree, the yield. The oxidation rates observed on three different extracts is illustrated in Fig. 6, along with an average value calculated from 17 experiments using 8 different water extracts. All reactions were at pH 6.0. The component of the extract which controls this reaction rate has not been isolated. Its presence is further illustrated by comparative oxidation and degradation studies carried out in water and in extract. In all cases, reactions proceed more rapidly in the extract, increasing approximately seven fold in the case of DHQ disappearance during oxidation. Fig. 7 illustrates the rates of Q degradation under oxidizing conditions in extract and in water.

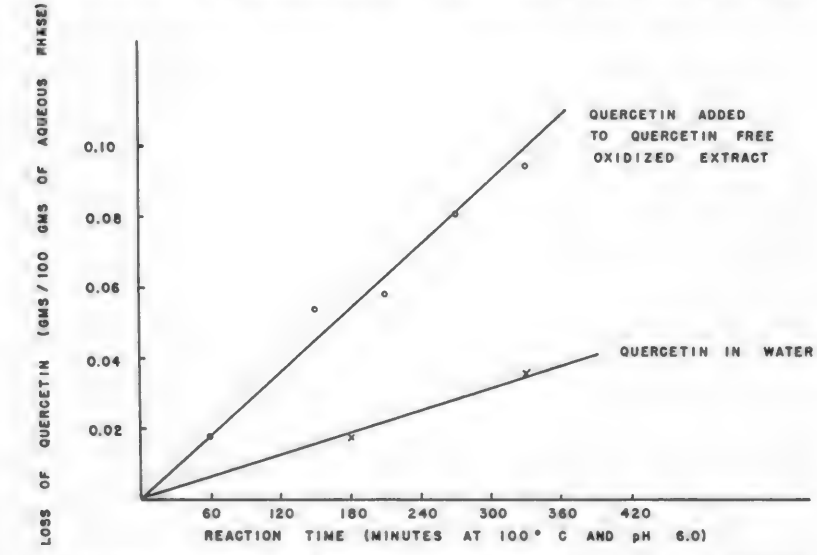
LOSS OF QUERCETIN (GMS / 100 GMS OF AQUEOUS PHASE)
0.10
0.08
0.06
0.04
0.02
QUERCETIN ADDED TO QUERCETIN FREE OXIDIZED EXTRACT
QUERCETIN IN WATER
60 120 180 240 300 360 420
REACTION TIME (MINUTES AT 100° C AND pH 6.0)

Fig. 7.—Loss of quercetin under oxidizing conditions in presence of excess quercetin.

Discussion of Mechanism of Reaction

The following mechanism is proposed as most nearly explaining the experimental results:

(1) DHQ + $(OH^- \rightleftarrows$ (Intermediate such as an enolate of DHQ)

(2) DHQ Intermediate) + $0_2 \longrightarrow$ Soluble Q $\rightleftarrows$ Insoluble Q

(3) Q (under reaction conditions) $\longrightarrow$ degradation products

(4) (DHQ Intermediate) (Under reaction conditions) $\longrightarrow$ Non-Q products.

Weissberger(17) has shown that in autoxidation of hydroxy ketones (e.g. benzoin) the rate of enolization (racemization) and the rate of autoxidation are identical, with the conversion to the enol form being rate controlling.

Under reaction conditions used in our laboratory (OH^-) remains constant, which permits DHQ disappearance step (1) to follow pseudo first order kinetics as indicated in Fig. 6. This reaction appears to be rate controlling with the average value for k_1 in the expression $\frac{-d\,(DHQ)}{dt} = k\,(DHQ)$, being 14×10^{-3} min.$^{-1}$

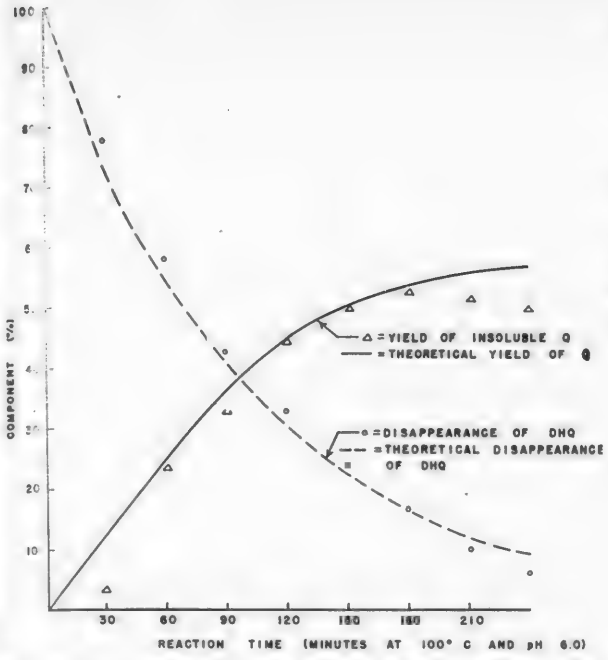

Fig. 8.—Theoretical and actual rate of DHQ disappearance and Q formation.

$$\text{DHQ} \xrightarrow[k_1]{OH^-} \text{(Intermediate)} \xrightarrow{k_4} \text{Non-Q Products}$$

$$\text{(Intermediate)} \xrightarrow[k_2]{O_2} \text{Q Soluble} \xrightarrow{k_3} \text{Degradation Products}$$

$$\text{Q Soluble} \rightleftarrows \text{Q Insoluble}$$

$$C = \frac{k_1 k_2 C'_{t^\circ}}{k_2 + k_4 - k_1}\left[\frac{e^{-(k_2+k_4)t} - 1}{k_2 + k_4} - \frac{e^{-k_1 t} - 1}{k_1}\right] - (k_3 C_{Satn.})t$$

where:

C = Amount of Q present at time t.
$C_{Satn.}$ = Saturation concentration of Q in solution.
C'_{t° = Initial concentration of DHQ = 0.43 gms. DHQ per 100 gms. of extract (Reaction #62).
k_1 = 10×10^{-3} min.$^{-1}$ (measured).
$k_3 C_{Satn.}$ = 0.28×10^{-3} gms. per 100 gms. per min. (measured).
k_2 = 56×10^{-3} min.$^{-1}$ (assumed value). First order kinetics assumed.
k_4 = 14×10^{-3} min.$^{-1}$ (assumed value). First order kinetics assumed.

Fig. 9.—Possible kinetic equation for calculation of Q formed.

Table 4.—ESTIMATED "DHQ BALANCE" FOR A TYPICAL LABORATORY OXIDATION.

	Yield %*
Insoluble Q Obtained	70†
Soluble Q in Mother Liquor	4†
Q Formed then Degraded	11†
DHQ in Mother Liquor	4
DHQ Degraded to Non-Q	11
Total	100

*Basis of original DHQ present in extract.
†Total DHQ converted to Q during reaction is approximately 85% of original DHQ.

for a variety of extracts at pH 6. The rate of Q formation is effected by oxygen concentration in harmony with step (2), but yield of Q does not equal DHQ consumption due to competing steps (3) and 4). The existence of step (3) reactions was demonstrated by subjecting Q to oxidizing conditions in DHQ-free oxidized extract. Excess of Q was present so that the mixture remained saturated with Q. Under these conditions, Q was destroyed at the linear rate of 2.8×10^{-4} grams per 100 grams of reaction mixture per minute (Fig. 7).

Step (4) would be expected to include a variety of reactions, one of which was demonstrated by subjecting extract to all conditions used in an oxidation excepting that air was carefully replaced by nitrogen. In a 6-hour period, 69% of the DHQ disappeared with only 2.2% of Q being formed. Oxidation of the resulting mixture indicated that no appreciable portion of the non-Q products formed under nitrogen could be converted to Q by oxidation. The rate constant for DHQ disappearance in a nitrogen atmosphere was 3.4×10^{-3} min. $^{-1}$.

In addition to Q formation, treatment of DHQ in alkaline media has been shown to give relatively insoluble sodium salts(18) and racemization from the (d) to the (dl) forms of DHQ. Mahesh and Seshadri(9), in particular, have shown that a total of four forms and their mirror images are possible for DHQ and that some of these do not readily dehydrogenate, but instead dehydrate at the $C_2 - C_3$ carbons. Geissman (14, 15) has shown that benzylcoumaranones are readily formed by the action of base on chalcone-flavanone systems.

The kinetics of a reaction in which Q yields were relatively low (53%) was studied. An equation (Fig. 9) was derived to express the rate of Q formation. By using observed values for k, linear loss for Q degradation and assumed values for k_2 and k_4 for this experiment, #62, the predicted values plotted lie close to the observed curve (Fig. 8). The first order disappearance of DHQ for the same reaction is shown by plotting values based on $k_1 = 10 \times 10^{-3}$ against measured data.

From the foregoing a "DHQ balance" for an extract oxidation can be estimated as shown in Table 4.

Summary

Dihydroquercetin present in the water extract of Douglas-fir bark has been oxidized to quercetin employing air in substantially neutral solutions. The yields obtained (65–80%) exceed those obtained by some of the more costly chemical conversions and make the process suitable for large scale application. Pertinent reaction variables are alkalinity, air rate, temperature, concentration, and extract composition.

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Discussion

Irwin A. Pearl (Institute of Paper Chemistry): Are there any known methods for isolating dihydroquercetin from Douglas-fir bark?

Dr. Gregory: Ether extraction from bark and water solution of bark extracts are methods.

J. F. Saeman (U. S. Forest Products Laboratory): What technique was used for the analysis of "Q" and "DHQ"?

Dr. Gregory: Gravametric and ultraviolet absorption.

Samuel A. Woodruff (Battelle Memorial Institute): Were catalysts tried in this reaction?

Dr. Gregory: Yes, metal oxides and peroxide were tried with little success.

Samuel A. Woodruff: What uses are there for quercetin? Are there any commercial uses?

Dr. Gregory: There are no large uses at the present. It has some promise in pharmaceuticals and anti-oxidants.

Reavis Sproull (Philip Morris Co.): Has quercetin been tried for fungicidal properties?

Dr. Gregory: No.

J. S. Ruhoff (Monsanto Chemical Co.): What will quercetin cost by this process?

Dr. Gregory: This will be part of an integrated program, and cost will depend in part on other products. A developmental price will have to be established during test marketing.

The Anatomical Basis of Dimensional Changes of Wood in Response to Changes in Moisture Content[1]

J. D. HALE

Presents the hypothesis that dimensional changes of wood in response to changes in moisture content are mostly the result of dimensional changes of the vertical cells (prosenchyma). The paper demonstrates how radial seasoning checks originate at the junction of rays and thick-walled prosenchyma and indicates that internal separations may be more common in seasoned wood than is generally believed. The application of this fact to studies of wood fractures is suggested.

Summary

A GENERAL HYPOTHESIS is presented to explain the anatomical basis of dimensional changes of wood in response to changes of moisture content. Such shrinkage (and swelling) is mostly the result of dimensional changes of the vertical cells (prosenchyma) which are the principal constituents of wood. Although the wood rays admittedly act to restrain radial dimensional change, the anatomical structure and arrangement of the vertical cells causes vertical tissue to dominate dimensional change so effectively as to make the radial shrinkage of wood significantly less than the tangential, regardless of the rays in exogenous species. This hypothesis is supported by its conformity with other known facts of shrinkage of both normal and abnormal wood.

Illustrating the mechanics of shrinkage, the paper demonstrates how radial seasoning checks originate at the junction of rays and thick-walled prosenchyma and indicates that internal separations, more or less microscopic but sufficient to affect mechanical properties, may be much more common in seasoned wood than is generally supposed. The obvious application of this fact to studies of wood fractures is suggested. The paper indicates that competent anatomical observation is a prime necessity for really critical study of properties of wood that may be affected by changes of moisture content, it being reasonably apparent that all properties are in some way affected.

As the fifth and final paper of a series reporting observations made on shrinkage reaction of different cellular tissues of wood at the Ottawa Laboratory of the Forest Products Laboratories of Canada, the present paper necessarily cites significant conclusions from the previous papers published in the FOREST PRODUCTS JOURNAL.

Hygroscopic Character of Normal Wood

The hygroscopic nature that causes wood to shrink or swell in response to changes within a certain range of moisture content is an outstanding characteristic of great technological significance. It is a natural result of the physico-chemical composition of the cell walls and of the anatomical structure.

In view of the intimate connection between the cell structure of wood and its hygroscopic peculiarities, it seems probable that any procedure that can satisfactorily eliminate shrinkage and swelling must be founded on adequate appreciation of its anatomical basis. This paper, therefore, attempts to indicate the general anatomical basis of dimensional change in response to changing moisture content.

Observations made previously at the Ottawa Laboratory of the Forest Products Laboratories of Canada regarding the different amounts of shrinkage contributed respectively by prosenchyma[2] and wood rays toward the over-all shrinkage of wood have been reported in the work of D. C. MacIntosh, who demonstrated particularly the effect of rays in restraining the shrinkage of wood across the grain in a radial direction (7, 8, 9, and 10)[3], and indicated the possibilities of a technique for analyzing the fractional increments contributed toward the shrinkage of wood as a whole by the different component tissues (9). Measurement in red oak and beech of shrinkage in springwood and summerwood without broad rays has indicated a tangential to radial shrinkage ratio for springwood of about 2 to 1 and for summerwood of about 1 to 1. The author, therefore, suggests that the fine ray tissue is responsible for the large tangential to radial ratio of the relatively weak springwood.

By assigning to fine rays a shrinkage potential somewhat similar to that measured for broad rays, an equation was obtained based on a derivation suggested by Pentoney (13) in which the shrinkage of all rays is combined on the basis of total ray volume in wood. Computation of this equation considers the relative elastic moduli both of rays and of rayless wood and provides a theoretical curve showing the relation between radial shrinkage of transverse sections of oak and beech containing various amounts of ray tissue from 100 per cent to the theoretical zero for wood with no rays at all (9). The computed curves, of course, conform satisfactorily to the data from actual measurement.

These computations indicate that although the characteristically small

[1] A contribution of the Ottawa Laboratory, Forest Products Laboratories of Canada, Forestry Branch, Department of Northern Affairs and National Resources, Ottawa, Ontario.

The Author: J. D. Hale, Head of the Section of Wood Structure in the Ottawa Laboratory of Forest Products Laboratories of Canada, received B. A. and M. A. degrees from Harvard University. He has been with the FPL of Canada since 1921, principally in the field of the relationship between anatomy and technological characteristics exhibited by wood in processing and service.

[2] The ancient term prosenchyma is convenient for the purposes of this paper to signify the vertical elongated pointed cells that typically compose most of the volume of wood as opposed to the wood rays which are bands of short cells oriented across the grain in the radial direction.

[3] Numbers in parentheses refer to literature cited.

shrinkage of rays in the radial direction is in general highly significant in causing radial shrinkage of wood to be less than that in the tangential direction, not all of the difference between radial and tangential shrinkage in the species studied can be attributed to the restraining action of rays (10). Since the vertical cells of wood occupy most of the volume, the contribution of vertical tissue to dimensional change of wood must be given adequate consideration.

Anistropic Dimensional Changes of Wood

Why wood normally shrinks across the grain rather than along the grain

The observations of Nägeli (12) and others reported about a century ago seem to have provided the first evidence for the micellar theories of cell structure which currently provide the basis for explaining the mechanism of normal shrinkage and swelling of wood. That normal wood shrinks principally across the grain and but little along the grain is explainable: 1) by the fact that the component fibrils of the walls of prosenchyma cells are preponderantly parallel to the principal cell axis; and 2) that moisture present in the cell walls is held between the fibrillar strands of crystallites so that reduction of this moisture content fosters the formation of natural physicochemical bonds that act to draw the fibrils closer together, filling the gaps formerly occupied by water. As a natural result, the cell wall shrinks principally in a direction perpendicular to that of its fibrillar components. The fact that the direction of the principal axes of prosenchyma cells is the direction of the grain, insures that the shrinkage of normal wood prosenchyma is preponderantly across the grain rather than along the grain. As the behavior of cell masses naturally determines the behavior of wood, it appears normal that wood shrinks typically across the grain, and but little along the grain, embodying in this respect the trend of dimensional changes undergone by its component cells. This explanation of the basis of normal shrinkage and swelling appears to be generally acceptable (3, 6) and widely believed.

When abnormal patterns of behavior in dimensional changes of wood are encountered—as in compression-wood which shrinks along the grain—it is a notable fact that the predominant fibrillar angle of the cell wall components is not parallel to the long axes of prosenchyma cells and so imparts a significant longitudinal increment to shrinkage or swelling (3).

Other apparent abnormalities in shrinkage as in instances where abnormally large amounts of shrinkage along the grain are encountered in woods that are below the normal specific gravity for their species (5) may similarly be explained by fibrillar angles that are predominantly slanted from the long axes of the prosenchyma cells. While it seems important to study such apparent exceptions to the normal pattern of behavior in the shrinkage of wood, it is equally or more desirable to observe how in normal shrinkage of wood the fibrillar angle of prosenchyma cell wall components contributes effectively toward making the shrinkage in a radial direction less than that in the tangential direction.

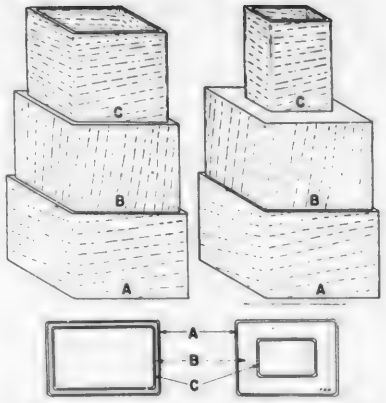

Fig. 1.—Conventional diagram, highly magnified, illustrating structure of secondary walls of normal thin-walled (left) and thick-walled prosenchyma cells (right) dissected to indicate three differentiated layers in transverse (lower) and side view (upper). Dotted lines indicate direction of alignment of submircoscopic components which in outer and inner layers A and C is nearly perpendicular to that of the thick middle layer B. Middle layer B, because of its relatively great thickness in thick-walled cells, can dominate shrinkage causing cells to shrink in diameter rather than length. In abnormally thin-walled cells where all layers have more nearly comparable thickness, middle layer B does not completely dominate and such cells may therefore shrink in length as well as in diameter.

Structural Characteristics of Prosenchyma

While early observations on cell wall structure have drawn attention to the anisotropic nature of submicroscopic components of the cell wall, it is only in fairly recent times that the current conception of a definite organization of cell wall material as suggested by Kerr and Bailey and others has become established (1, 4, 14, 15). According to current theory, the wall of a prosenchyma cell is regarded as consisting of successive layers, each characterized by distinctive alignment of its crystallitic components.

The typical prosenchymatous cell wall has been found to consist principally of three distinguishable layers (1, 14) aside from the outermost primary layer which is typically so thin that, except for its role in intercellular cohesion, it may perhaps be disregarded in this particular discussion of normal shrinkage.

The secondary wall which is regarded as the important part of the cell wall in determining dimensional changes of the individual tubular cells is typically composed of three layers which are characterized by specifically different alignment of their crystallitic components (Fig. 1.). The external and the internal layer of the secondary wall each has in common the characteristic of being formed of fibrillar strands aligned preponderantly like helical wrappings at an angle approximately perpendicular to the long axis of the cell. The intermediate layer of the wall between these outer and inner linings is usually much the thickest of the three, and is generally composed of fibrillar strands that are approximately parallel to the long axis of the cell. In the average wood this middle layer of the cell wall is so substantially thicker than the thin outer and inner skin-like layers that its dimensional changes in shrinking or swelling appear predominant in affecting the dimensional changes of the cell.

Since the secondary walls of prosenchyma cells are subject to wide variation in average thickness—from a minimum in springwood to maximum thickness in summerwood—the proportion of the wall contributed by the central layer varies according to the overall thickness of the whole wall. The inner and outer skin-like layers, however, appear practically unchanged, regardless of the variations in thickness of the cell wall as a whole. In summerwood prosenchyma, therefore, where the intermediate layer of the wall is typically thickest, its dimensional reactions as wood dries may be practically unaffected by the opposition of the relatively thin outer and inner skins of the secondary wall. In springwood, however, or wherever prosenchyma cell walls are thinnest, the relative thinness of the middle layer renders it more nearly comparable to the thin neighboring layers on each side. The result is that, in the drying of springwood, the outer and inner layers of the thin cell walls may prove strong enough to produce noticeable effects on cell dimensions. It will therefore be obvious that the shrinkage of summerwood cells—where the thick central layer of the cell wall dominates the shrinkage—will be different from the shrinkage of springwood cells in which the surface layers of the cell wall may effectively contribute toward determining the shrinkage. The different structural alignments

in these three layers of the secondary wall must be kept in mind for explanations of the phenomenon of normal shrinkage that occurs when moisture originally present between the aligned crystallites in the cell wall is removed.

Attention may be redirected here to the current conception of the mechanism of shrinkage according to which such moisture as is present in the saturated wall of prosenchyma cells is believed to be held between the fibrillar strands of crystallites. Where the strands are predominantly parallel or nearly so to the length of the cell, as in the thick-walled prosenchyma of summerwood, the shrinkage resulting from consolidation of the fibrils is principally shrinkage in diameter but not in length of these tubular cells. Such, of course, is the conventional explanation previously cited why normal wood shrinks across the grain, causing boards to shrink principally in width but typically little in length—the behavior of wood being the resultant of the behavior of its cell masses.

There is evidence, therefore, that the thick-walled tubular cells such as those that compose summerwood shrink in diameter and not in length because these cells have the extra-thick principal layer of their cell walls composed preponderantly of fibrils parallel to the long cell axis. Since this is the direction of the "grain" of wood, the shrinkage takes place typically and preponderantly across the grain. While it is to be expected that shrinkage stresses exerted by the inner and outermost layers of fibrils helically wrapped at (nearly) right angles to the main axis tend to shorten the cell, these layers are so relatively thin and insignificant as to have practically no shortening effect on the summerwood prosenchyma, which similarly is able to resist compression from vertical shrinkage of the rays. There is obviously some difference in structural balance of the cell wall elements that causes the shrinkage behavior of springwood to be different from that of summerwood.

Springwood Prosenchyma Cell Wall Organization Tends to Minimize Transverse Shrinkage

In springwood, where prosenchyma cell walls are typically thin, the intermediate layer of the cell wall may be relatively so thin and weak that the shrinkage accompanying loss of moisture permits the outer and inner layers —composed of fibrils helically arranged almost perpendicular to the cell axis—to cause some resultant shrinkage to be transmitted so as to reduce the length of the thin-walled wood cells. Since part of the shrinkage goes to reduce the length of such thin-walled cells, not all the shrinkage can be transmitted to decrease the cell diameter. The obvious result is that the lightweight thin-walled cells of springwood or elsewhere in woods of abnormally light weight for their kind, shrink less across the grain but somewhat more along the grain than the dense thick-walled cells of summerwood. Instances of anomalous shrinkage behavior corroborating this explanation of the cell wall mechanics of shrinkage are well known to technologists. This would explain why normal springwood exhibits slight but significant shrinkage along the grain and why some longitudinal shrinkage is likely to be encountered in wood specimens that are abnormally light in weight for their kind (2, 5) since such lightweight wood presumably has the typical thin-walled cell structure. Contributing to the longitudinal shrinkage of wood, it also appears that the shrinkage of rays in the direction of prosenchyma cell axes must exert a more noticeable effect on thin-walled springwood prosenchyma than on that which is so relatively unyielding in summerwood. This tendency of thin-walled prosenchyma to shrink somewhat in all directions naturally contributes toward causing its transverse shrinkage in cell diameter to be less than the transverse shrinkage of the denser summerwood. The tendency toward longitudinal shrinkage of thin-walled prosenchyma cells appears to account for the longitudinal shrinkage observed in woods of abnormally low density.

Inclined fibril angles are of course common in compressionwood and although compressionwood is characterized by prosenchyma with thick walls and abnormally high density for its species, its fibrillar orientation in prosenchyma cells is widely inclined from the cell axes (1, 3). Compressionwood is, of course, noted for shrinkage along the grain because the fibrillar angle of compression wood prosenchyma deviates so widely from the long axes of the prosenchyma.

In woods of abnormally low specific gravity for their kind, the longitudinal shrinkage of prosenchyma is somewhat analogous to that of compression wood in that it arises from the proponderant inclination of fibrillar angles of the components of the secondary wall. However, since such thin-walled prosenchyma of lightweight wood is not composed entirely of fibrils inclined at a considerable angle to the cell axes, such material does not ordinarily exhibit as great longitudinal shrinkage as may be evident in extreme forms of compression wood.

In discussing the shrinkage exhibited by the prosenchyma cells, there seems no reason to suggest here that the intrinsic capacity to shrink or swell normally in diameter is necessarily different in radial or tangential direction. The fact that wood typically exhibits more tangential shrinkage than radial can be due to the annual ring habit and the consequent reaction between unyielding summerwood of high potential shrinkage and the more pliant springwood with characteristically smaller natural tendency for transverse shrinkage.

The fact that thin-walled prosenchyma, typical of springwood, has a characteristic cell-wall organization contributing naturally to less transverse shrinkage than that of summerwood prosenchyma supplements the annual ring structure in providing a mechanism that compels the radial shrinkage of wood to be less than the tangential shrinkage. This eliminates any necessity to suppose that fibrillar or micellar characters associated with bordered pits on the radial walls have sufficient effect to explain the difference between radial and tangential shrinkage. Even if the difference in shrinkage were explainable by such a difference between the radial and tangential cell walls in species characterized by extensive tracheary prosenchyma, the simple fact remains that tangential shrinkage is greater than radial shrinkage in all exogenous woods whether or not a preponderance of radial pitting is present. Obviously the high tangential to radial shrinkage ratio that is typical of all woods cannot be caused by such an anatomical feature as abundant radial pits in woods where the feature does not occur. Tangential shrinkage of exogenous woods would exceed the radial shrinkage even though transverse shrinkage of isolated prosenchyma is symmetric.

It must be apparent that shrinkage of wood in a radial direction is necessarily a summation of increments of high shrinkage in the relatively dense summerwood and low shrinkage in the relatively light springwood. In the tangential direction, however, the large amount of shrinkage undergone by the summerwood prosenchyma dominates the overall shrinkage by forcing the relatively pliant springwood to shrink with it. In the course of shrinking tangentially, the softer springwood which is attached to and sandwiched between layers of relatively inflexible summerwood is necessarily squeezed into approximate conformity with the greater shrinkage of the summerwood. Tangential shrinkage of wood therefore will naturally exceed the shrinkage in a radial direction since the radial shrinkage is necessarily composed of small increments of high shrinkage representing the radial thickness of

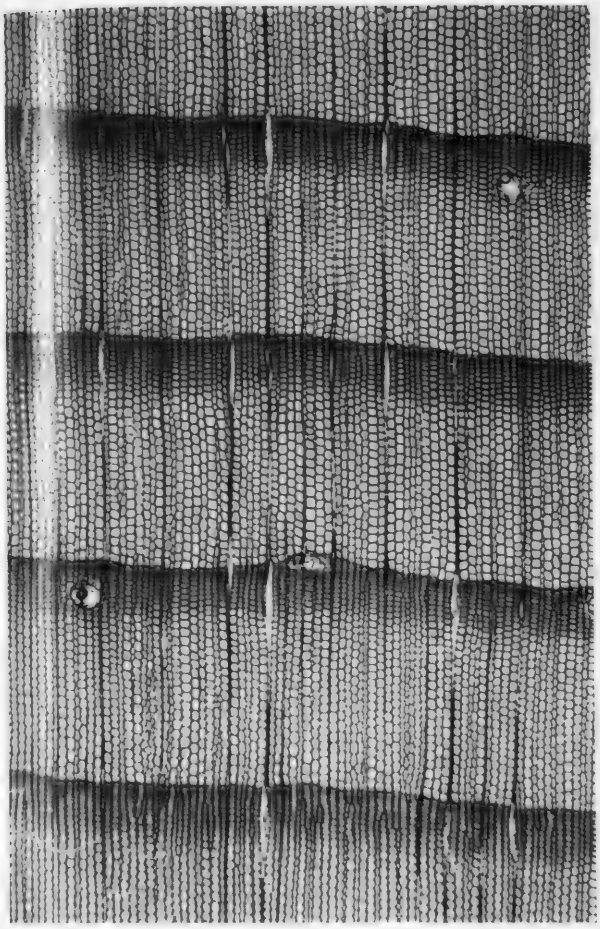

Fig. 2.—Pinus resinosa Ait. trans. x 30. Separations between rays and prosenchyma occur as result of stresses in drying where summerwood prosenchyma of high potential shrinkage is in contact with rays of relatively low radial shrinkage potential. Thin-walled springwood prosenchyma has low potential shrinkage and is sufficiently pliant to conform to shrinkage of rays without separating.

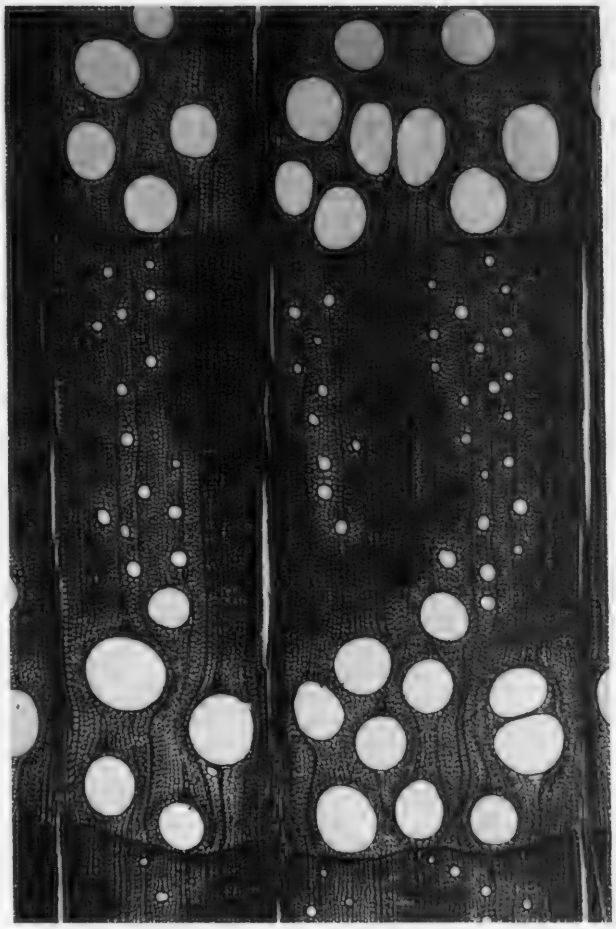

Fig. 3.—Quercus borealis Michx. F. trans x 30. As in Fig. 2, separations between rays and prosenchyma in summerwood may occur in hardwoods where notable contrast in texture exists between springwood and summerwood.

summerwood, interrupted by increments of low shrinkage representing springwood.[4]

Discussion

From results just cited, it appears that the radial shrinkage of wood will naturally be smaller than the tangential in species characterized by perceptible difference in texture of springwood and summerwood. In explaining the anatomical basis of this situation, there is no necessity for assuming that the "radial" and "tangential" walls of vertical cells have any intrinsic structural differences.

One aspect of the radial shrinkage of springwood has been explained by suggesting that the relatively flexible springwood prosenchyma may be rather effectively held in position and prevented by the less shrinkable rays from realizing the full radial shrinkage potential. That the vertical shrinkage of rays may impart some shrinkage along the grain of thin-walled prosenchyma has already been noted. The vertical cells of summerwood on the contrary, being thick-walled, are correspondingly stiff and more readily able—because of their high potential for shrinkage across the grain during seasoning—to exert some compressive effect radially on the rays and to resist compression effects along the grain.

The naturally low transverse shrinkage of springwood prosenchyma, therefore, tends to approximate more nearly the low radial shrinkage of rays than does the greater shrinkage of summerwood prosenchyma. In both regions of the annual layer, the radial shrinkage of wood is the resultant of the low shrinkage of the rays and that of the vertical wood cells, but the transverse shrinkage potential of the strong summerwood prosenchyma may be so great as to overshadow the restraining effect of rays.

Tangential shrinkage of wood on the other hand is not directly affected by the restraint of rays, since the tangential shrinkage of ray tissue seems to be relatively high, approximating that of summerwood (9). Moreover, being mechanically strong, the action of summerwood can dominate the softer flexible springwood so that the tangential shrinkage of wood as a whole, which is the resultant tangential shrinkage of springwood and summerwood shrinking together, is likely to approximate the relatively large tangential shrinkage potential of the summerwood (10).

Radial shrinkage across an annual ring on the other hand is necessarily the sum of the low radial shrinkage of springwood plus the radial shrinkage of the summerwood. The summated radial shrinkage of summerwood and springwood (which constitutes the overall radial shrinkage of wood), therefore, is necessarily less than the tangential shrinkage. This would be so, aside from any effects of rays, because of the low diametric shrinkage of springwood prosenchyma. The annual ring structure provides continuous tangential bands of thick-walled summerwood prosenchyma which assures uniformly high tangential shrink-

[4] This explanation why tangential shrinkage exceeds the radial shrinkage has been credited to Mörath on the shrinkage of beech. As a result examination of the particular paper cited in this connection (11) does not reveal reference to such a shrinkage mechanism, it appears that some other paper should have been cited.

age, but since the radial shrinkage of prosenchyma must contain increments from relatively wide springwood areas where the shrinkage is less than in summerwood, the radial shrinkage potential of wood must typically be less than tangential shrinkage. It is evident, therefore, that radial shrinkage of exogenous woods must necessarily be less than the tangential shrinkage as a natural consequence of the arrangement of prosenchyma in annual rings and without any help of the rays. When, to such normal anisotropy, the demonstrated mechanism of rays in restraining shrinkage is added, there seems to be an abundance of anatomical characteristics that contribute toward differentiating radial and tangential dimensional change.

The possible effect of rays in facilitating intercellular separations in seasoned wood suggests that the boundaries between rays and prosenchyma should be carefully studied in the appraisal of fractures incurred in testing timber specimens in air-dry condition.

Implications of the situation discussed here and specifically indicated (7, 8, 9, 10) in previous work of the Laboratory and others as to the differences in shrinkage potential between rays and springwood or summerwood prosenchyma provide some insight into the origin of seasoning checks that will facilitate critical appraisal of fractured test specimens. The difference in shrinkage potential in the radial direction of rays and the neighboring vertical tissue indicates that the rays are most likely to become regions of local separation, particularly in the summerwood of species characterized by extreme contrast in density of summerwood and springwood (see Figures 2 and 3).[5]

Since such microscopic separations are common in seasoned wood, it seems probable that unduly large numbers of these breaks could become extended in drying so as to contribute to weakening certain mechanical properties of wood. Instances where wood specimens of apparent good potential quality fail unexpectedly under small loads are probably familiar to most technologists. Critical examination of such wood material for evidence of microscopic separations would help to explain instances where superficially good-looking wood has low mechanical strength.

In view of the discrepancies reported (9, 10) between the potential shrinkage of rays and vertical tissue, it is evident that in seasoned wood there must be rather severe local stresses wherever rays and dense vertical tissues are in contact. Thus, if prong-test specimens similar to the type employed for observing stresses in wood during kiln-drying could be cut sufficiently narrow so as to contain only one ray, and with that ray along one radial side, the prongs would curve appropriately away from the rays, unless the vertical tissue and the rays had already separated because of the stresses.

[5] Such separation may be commonly encountered in species with prominent summerwood composed of cells with relatively thick walls. In a recent study at the Ottawa Laboratory, it was observed that penetration of oil-type preservative in wood is significantly facilitated by separations in seasoned summerwood.

Conclusions

1. Anatomical characteristics of wood discussed herein that have demonstrable effects on the changes of dimensions in response to changing moisture content of exogenous species are:

A. Submicroscopic structure of the secondary walls of prosenchyma cells.
B. The annual ring structure of wood.
C. The wood rays.

2. The effect of rays to restrict radial shrinkage of wood, thereby contributing to make the radial shrinkage less than the tangential shrinkage, has been indicated.

3. This paper has particularly indicated that the conventional explanation of the basic mechanism of shrinkage lies in the secondary walls of the prosenchyma cells which bring about the "normal" type of wood shrinkage across the grain with very little shrinkage along the grain.

4. This explanation of normal shrinkage accounts for the fact that the amount of shrinkage undergone by normal wood in seasoning may be expressed as a function of the wood's density.

5. Instances of excessive shrinkage of wood along the grain are explained by the predominant inclination of fibrillar angles in components of the secondary walls:

A. Where the prosenchyma cells are particularly thin-walled as in springwood or in wood with particularly low density for its species.
B. Where prosenchyma is otherwise abnormal, as for example, in compression wood where an abnormal fibrillar angle dominates the cell walls.

6. Aside from the restraining effect of rays on shrinkage of wood, the normal shrinkage potential of prosenchyma cells and the annual ring structure of exogenous wood act together in rendering the radial shrinkage significantly less than the tangential shrinkage.

7. To explain why radial shrinkage of wood is less than tangential shrinkage, it is unnecessary to assume that radial and tangential walls of prosenchyma cells in general have any basic structural difference.

8. The fact that rays differ significantly from prosenchyma, in radial and vertical shrinkage and in mechanical strength, contributes to develop separations in wood as a result of the stresses that:

A. Occur during drying of wood.
B. Develop into the familiar radial seasoning checks visible on end surfaces.

9. When the rays are involved in such seasoning checks, the separations occur typically between the rays and prosenchyma or within the ray.

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Swelling of Paint Films in Water X Rate of Penetration of Water, Permeability o Water Vapor, and Penetrability to Air in Relation to Water Absorption

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Differing theories exist on resistance of house paints to blistering. Tests were made to measure the permeability to water and water vapor and the ability to breathe of some paints for which water absorption and swelling had already been determined. Factors are discussed which apparently affect the speed of penetration into various coatings.

PREVIOUS ARTICLES in this series (5)[2] reported the extent to which free and bound films of various paints and paint vehicles absorb water and swell when soaked in water. The data suggest strongly that the absorption and swelling of paints in water may be closely related to their tendency to blister and peel under practical conditions of service on houses. Those house paints that are known from actual experience to blister easily are also high in absorption and swelling, whereas those paints similarly known to be relatively resistant to blistering and peeling are also low in absorption and swelling.

Other workers have observed a relation between water absorption and blistering of coatings (30, 35), both on wood (8, 19) and on metal (1, 17, 20, 23, 27, 28). To compare water absorption with tendency to blister, there is need for more quantitative data on blistering pressure (18) or other direct measure of blistering.

American technologists often emphasize another property of coatings, their permeability to water vapor, as a measure of sensitiveness to moisture blistering. As far back as 1934, Gardner (12) suggested that readily permeable paints would resist blistering, and proposed to make permeable paints by incorporating porous pigments such as diatomaceous silica. It was thought that such paints "breathe" sufficiently to let water escape from the painted surface of wood faster than it can penetrate through boards from behind (4, 8, 15, 31). So-called "breather-type" paints have been sold commercially, but examination of some of them has failed to confirm that they have greater permeability than do ordinary paints. They did prove more resistant to blistering and lower in absorption and swelling than most ordinary paints, however, but paints may be highly resistant to blistering and yet low in permeability (34). It remains to be determined whether extremely high permeability affords reliable protection against blistering.

The differing theories on resistance to blistering made it desirable to measure the permeability and ability to breathe of some of the paints for which the absorption of water and swelling had already been determined. It was of interest to learn: 1) how long it takes for water in contact with the exposed surface of high- and low-swelling coatings to penetrate to the interface with the substrate, 2) the relative permeability of free films to water vapor, and 3) the penetrability of free films by dry air under a moderate difference in pressure.

The composition of the paints used in these tests was reported in papers VI and VII of the series (5).

Time Required for Water to Penetrate

Glass microscope slides 1½ by 3 inches in size were marked with crossed stripes of an aqueous solution of cobalt chloride containing a very small proportion of methyl cellulose. The markings, ⅜ inch wide, were blue in color when dry, and turned pink when exposed for a few minutes to air with a relative humidity of 65 per cent or more. They returned promptly to the original blue color when brought back to air with a relative humidity of 30 per cent or less. The weight of the markings was determined by weighing the slides before and after the solution was applied. To determine the density of the marking material, dried coatings on glass were scraped off with a razor blade and measured by the pycnometric method in kerosene. The thickness of the markings, calculated from the weight, area, and density, was 0.11 to 0.17 mil.

The marked slides were coated with paint at the desired thickness with doctor blade, suction plate, and suitable shims. Five single-pigment, raw linseed oil paints of pigment volume 0.30, pigmented with basic carbonate white lead, antimony oxide, titanium dioxide, zinc oxide, and magnesium silicate, respectively, were tested. The first two pigments make low-swelling paints, the fourth makes high-swelling paint, and the others make paints of intermediate swelling. For each paint, slides were prepared with coatings that were approximately 2 mils, 4 mils, and 6 mils thick when dry.

One complete set of specimens was tested for water penetration when the paint coatings were 8 days old. A second complete set was exposed for 15 days to ultraviolet light in a weatherometer, but without spraying with water. (It was found that water turned the cobalt chloride markings pink within one to two days, and the coatings became blistered over the markings soon afterward.)

To observe the rate of penetration of water, the test specimens were placed with the painted face down on glass rods that rested on the bottom of a shallow dish, and the dish was filled with water until about ½ inch of water covered the specimens. The blue markings were then readily visible through the water and glass against the white background of the paints. The lapse of time was observed between submergence and the first appearance of change from blue to pink color, between submergence and complete change from blue to pink, and between submergence and blistering of the coatings. Blistering could be detected without lifting the specimens out of the water because formation of a blister allowed the dissolved cobalt chloride to gather in a rounded droplet of solution that was easily recognized

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Numbers in parentheses refer to Literature Cited.

The Author: F. L. Browne received B. Chem. degree from Cornell U., Ph. D. in colloid chemistry from U. of Wisconsin. He joined the Forest Products Lab staff in 1918, helped develop casein glues for wood airplanes of World War I. In 1921–22 he was a National Research Fellow at Wisconsin. Since 1929 Dr. Browne has edited the General and Physical Chemistry Section of Chemical Abstracts.

Table 1.—TIME REQUIRED FOR WATER TO PENETRATE COATINGS OF LINSEED OIL PAINTS ON GLASS WHEN IMMERSED IN WATER

Composition of paint (pigment in linseed oil at pigment volume 0.30)	Coatings not weathered					Coatings weathered in artificial sunlight				
	Thickness of coating	Time required for first penetration	Time required for complete penetration	Time required for blistering	Water absorbed by free film in 3 days[1]	Thickness of coating	Time required for first penetration	Time required for complete penetration	Time required for blistering	Water absorbed by free film in 3 days[1]
	Mils	Hr.	Hr.	Hr.	Percent by volume	Mils	Hr.	Hr.	Hr.	Percent by volume
Basic carbonate white lead	2.3	11	29	32	8.9	1.3	7	24	24	9.9
	3.8	13	29	29		3.8	7	35	29	
	6.9	13	48	37		6.6	7	35	35	
Antimony oxide	2.1	7	24	13	5.3	1.3	2	3	2	2.5
	3.6	10	24	13		3.1	2	12	5	
	7.3	13	31	24		6.4	3	24	18	
Rutile titanium dioxide	1.9	2	9	6	26.5	1.3	1/8	3	2	8.3
	3.5	7	13	11		2.9	2	8	5	
	6.9	11	24	13		6.4	3	24	18	
Zinc oxide	1.8	3	9	7	83.3	1.4	2	12	5	28.2
	4.1	3	24	24		3.7	2	24	24	
	7.0	3	24	24		6.1	3	12	35	
Magnesium silicate	1.6	2	9	6	56.2	1.4	2	3	3	9.9
	3.8	7	24	24		3.3	2	5	12	
	6.4	10	24	24		6.3	3	12	24	

[1] Data from Browne, paper VI (5)

by the variation in intensity of color fom center to edge of the droplet.

Results of the tests of time of penetration are reported in Table 1.

Water penetrated some portions of a paint coating much more rapidly than others. For example, with the unweathered coating of titanium dioxide paint 1.9 mils thick, pink spots strongly contrasting wth the rest of the blue stripes could be seen within two hours. The spots slowly increased in size and number. After six hours, about half the total area of the stripes were pink, the other half still blue. Nine hours elapsed before the last of the blue color changed to pink. All other coatings exhibited a similar course of events, although differing in time scale, with an initial appearance of pink in spots that grew slowly in size and number until all blue changed to pink. Essentially the same behavior has recently been reported by Pragst (26), who allowed an aqueous solution of methylene blue to diffuse through coatings of paint on glass.

Although more time was required for water to penetrate the thicker coatings of paint, the time was not always proportional to thickness. Thus with the unweathered coating of white lead paint 2.3 mils thick, first penetration was observed in 11 hours, and the coating 3 times as thick, 6.9 mils, was penetrated in 13 hours. Unweathered coatings of zinc oxide paint 1.8, 4.1, and 7.0 mils thick were all penetrated first in three hours. On the other hand, first penetration of coatings of antimony oxide, titanium dioxide, and magnesium silicate paints was always delayed by increased thickness at least as much as proportionality would indicate. With weathered coatings of all paints, first penetration usually occurred sooner than with corresponding unweathered coatings, and increased thickness delayed first penetration relatively little.

The relatively short time sometimes required for first penetration, and the lapse of time between first penetration and complete penetration, together with the variable relation between coating thickness and time of penetration, suggest that paint coatings have an exceedingly heterogeneous internal structure that is more readily penetrated in some places than in others (21, 29). Bell's (2) discussion of the structure of paint films, particularly his photographs of the formation of Benard cells and electron photomicrograph of a cross section of a paint film, furnish adequate explanation of the observed irregularity of penetration.

James (16) measured the time required for water to penetrate coatings of red iron oxide paints and the clear vehicles with which they were made by an electrical method. Most of his coatings were 1.6 mils thick, thinner than any of the unweathered coatings reported in this paper. Coatings of linseed-tung oil vehicle with or without pigments apparently were penetrated almost immediately, but their water content continued to increase for several days. Coatings of clear and of pigmented phenolic-resin varnish, linseed-rosin-epoxide resin, and linseed-pentaerythritol alkyd vehicle were penetrated in 15 to 90 minutes, but continued to gain water for several days.

As reported in Table 1, unweathered coatings of white lead and of antimony oxide paints, which are low in water absorption, always required a longer time for first penetration and nearly always took longer for complete penetration than coatings of similar thickness of the high-absorbing titanium dioxide, zinc oxide, and magnesium silicate paints. Among the weathered coatings, white lead paint remained slowest to permit either first or complete penetration, but antimony oxide paint, despite its low absorption, was penetrated about as rapidly as any of the other paints. For unweathered coatings, high absorption seems to hasten penetration, although the two are by no means exactly parallel. For weathered coatings, other factors appear to be more important than water absorption in determining speed of penetration.

Blisters usually appeared in the coatings over the stripes of cobalt chloride either somewhat before or at least soon after penetration was complete. It was difficult to tell when blistering began in the thicker weathered coatings of zinc oxide and magnesium silicate paints, because the coatings were too hard to yield readily in blisters, and the blisters, when they became observable, were relatively large and only gently curved. There was seldom any observable blistering where no stripes of water-soluble material were interposed between coating and glass. The pressure responsible for blistering arose therefore from osmosis (17). Adhesion may have been as badly impaired by penetration of water around as over the water-soluble stripes, but sufficient pressure to overcome the mechanical resistance of the film to flexing may have been lacking where there was no soluble material to give rise to osmosis.

Permeability to Water Vapor

The permeability of free paint films to water vapor was measured by the Payne cup method (22, 25). Distilled water was placed in the cup, and the paint film to be observed was clamped in position. The cup was then placed in a desiccator over calcium chloride in a room held constantly at 70° and the cup was weighed daily to

determine the loss of water through the paint film. Steady state conditions were reached within one day. The rate of loss during the second and third days, which was nearly constant, was taken as a measure of the permeability of the film. The permeability is expressed as the number of milligrams of moisture vapor lost per square centimeter of film area per day for a film 1 millimeter thick, which is known as the specific permeability, P_s. The relation is

$$P_s = \frac{ml}{qt}$$

in which m is the weight of water lost in milligrams, q is the area of film exposed in square centimeters, l is the thickness of the film in millimeters, and t is the time in days. The calculation assumes that permeability is inversely proportional to film thickness. The assumption is not always correct (7, 29), but the error is not serious for the comparatively small variation in thickness of the films used for the study.

Each film was weighed immediately before and again immediately after the permeability test. The film was then dried in a desiccator over calcium chloride and weighed once more. The difference between the second and third weighings was recorded as the moisture held by the film at the end of the test period. The difference between the first and third weighings was recorded as the change in weight (usually negative) of the moisture-free film during test.

The results with oil and oleoresinous films are recorded in Table 2, in which the films are arranged in order of decreasing absorption of water by the unweathered films when soaked for three days, as reported in prior papers (5). The films are separated into four groups according to the absorption of water by the unweathered films. These groups are: above 49, between 20 and 49, between 10 and 20, or below 10 per cent of water by volume. Results with latex films are similarly recorded in Table 3.

The results show that the permeability of paint films to water vapor is not primarily related to their water absorption. Among the unweathered pigmented oil and oleoresinous films, there was 100-fold variation in water absorption (0.8 to 86.4), but only 9-fold variation in specific permeability (0.06 to 0.54). For the group with absorption greater than 49 per cent (average 73.9), the permeability ranged from 0.15 to 0.30, and averaged 0.23. For the group with absorption less than 10 per cent, the permeability ranged from 0.06 to 0.33, and averaged 0.16. The next to the lowest permeability, 0.07, and the highest permeability, 0.54, occurred in the same group.

Although weathering usually decreased both water absorption and per-

Table 2.—SPECIFIC PERMEABILITY TO WATER VAPOR (AT 70° F.) OF FREE FILMS OF OIL AND OLEORESINOUS PAINTS, TABULATED IN ORDER OF DECREASING ABSORPTION OF WATER DURING 3-DAY SOAKING

Unweathered films						Composition of film		Weathered films				
Water absorbed on soaking for 3 days A/V_o	Prior paper of this series from which data for A/V_o were taken (5)	Specific permeability: P_s	Moisture absorbed during permeability test	Change in weight of dry film during test	Thickness of film	Pigment	Vehicle[1]	Water absorbed on soaking for 3 days A/V_o	Specific permeability: P_s	Moisture absorbed during permeability test	Change in weight of dry film during test	Thickness of film
Percent by volume		Mg. mm. per cm.^{2} per day	Gm. per 100 cc.	Gm. per 100 cc.	Mil			Percent by volume	Mg. mm. per cm.^{2} per day	Gm. per 100 cc.	Gm. per 100 cc.	Mil
GROUP WITH A/V_o MORE THAN 49 PERCENT												
86.4	VI	0.17	2.9	-0.3	3.3	Titanium-zinc, TZ_{25}	alkyd	20.2	0.11	1.3	-0.5	3.0
85.3	IX	.30	7.3	-1.4	4.1	Zinc oxide	RLO (36° F.)	28.0	.24	1.7	-.7	3.6
83.3	VI	.25	6.0	-.2	3.8	Zinc oxide	RLO	28.2	.31	2.2	+.1	3.7
73.5	VI	.15	3.6	-.5	2.9	Lead-zinc, LZ_{25}	alkyd	20.3	.08	1.3	-.7	3.0
64.2	VI	.27	1.0	-.1	4.5	Antimony-zinc, AZ_{25}	alkyd	20.2	.12	1.1	-1.0	2.8
62.5	VIII	.25	6.8	-1.5	4.1	Titanium-zinc, TZ_{25}	RLO					
61.8	VI	.19	1.8	-.4	2.9	Zinc oxide	alkyd	17.8	.10	.7	-.1	2.9
(56.2)[2]	VI					Magnesium silicate	RLO	9.9	.34	.9	0	3.1
Average 73.9		.23	4.2	-.6	3.7			20.7	.19	1.3	-.4	3.2
GROUP WITH A/V_o BETWEEN 20 AND 49 PERCENT												
40.3	VI	.23	1.1	-.6	3.0	Magnesium silicate	alkyd	12.1	.20	1.5	-.6	2.8
31.8	VI	.16	1.4	-1.9	4.2	Zinc oxide	RLO	14.2	.16	.8	-.3	3.9
29.8	VIII	.17	10.6	-1.9	3.9	Lead-zinc, LZ_{25}	RLO					
28.5	IX	.54	1.3	-.2	4.1	Titanium dioxide	RLO (36° F.)	5.3	.27	1.6	-.1	3.3
28.0	VI	.29	1.6	-.3	5.2	Magnesium silicate	RLO	14.9	.33	1.3	-.7	4.5
26.5	IX	.45	1.4	-1.2	3.9	Titanium dioxide	RLO	8.3	.26	1.4	-.7	3.0
24.3	VI	.19	1.5	-1.2	4.8	Titanium-zinc, TZ_{25}	RLO	16.1	.16	.9	-.7	4.5
23.2	IX	.07	1.1	-1.5	2.8	Commercial "Breather-Type"	(3)					
22.8	VI	.18	.9	-.2	2.7	Titanium-Antimony, TA_{25}	alkyd	4.8	.16	1.1	-.3	3.0
(21.8)[2]	VI	(1.39)[2]	(1.8)[2]	(-1.3)[2]	(7.5)[2]	No pigment	RLO					
Average 28.2		.25	2.3	-1.0	3.8			10.8	.22	1.2	-.5	3.6
GROUP WITH A/V_o BETWEEN 10 AND 20 PERCENT												
18.0	VI	.11	2.1	-.3	5.0	Antimony-zinc, AZ_{25}	RLO	14.7	.15	.8	-.4	4.8
16.6	VI	.25	1.0	-.6	3.0	Titanium dioxide	alkyd	3.4	.11	.6	-.3	3.2
16.3	VI	.15	2.8	-.8	4.6	Lead-zinc, LZ_{25}	RLO	15.7	.11	1.3	-.4	4.4
16.3[4]	(4)	.09	1.3	-.2	4.2	Commercial "Blister-Resistant"	(5)	8.6	.15	1.2	0	4.1
15.3	VI	.21	.7	-.2	5.2	Magnesium silicate	phen.	8.9	.15	.8	-.3	4.9
10.5	IX	.14	.5	-.5	4.8	White lead	RLO (36° F.)	5.4	.09	.8	-.4	3.6
10.3	IX	.19	2.0	-3.8	3.8	Zinc oxide	RLO (160° F.)	10.2	.15	1.1	-2.3	3.5
Average 14.8		.16	1.5	-.9	4.4			9.6	.13	.9	-.6	4.1
GROUP WITH A/V_o LESS THAN 10 PERCENT												
9.8	VI	.14	.4	-.2	4.8	Zinc oxide	phen.	5.3	.11	.4	-.3	4.2
9.7	VI	.10	.6	-.8	3.1	White lead	alkyd	4.2	.06	.2	-.6	3.0
(9.0)[2]	VI	(.32)[2]	(.5)[2]	(0)[2]	(4.4)[2]	No pigment	RLO					
8.9	VI	.14	.5	-.3	3.8	White lead	RLO	9.9	.10	.7	+.1	3.8
(7.7)[2]	VI	(.27)[2]	(.7)[2]	(-.6)[2]	(5.9)[2]	No pigment	alkyd	(4.8)[2]	(.19)[2]	(.8)[2]	(-.4)[2]	(4.9)[2]
7.3	VI	.14	.5	-.1	4.8	Antimony-zinc, AZ_{25}	phen.	4.2	.12	.7	-.6	4.5
6.8	VI	.26	1.2	-.9	5.4	Titanium dioxide	RLO	3.9	.25	.7	-.1	4.3
6.4	VI	.16	.7	-.1	4.9	Titanium-zinc, TZ_{25}	phen.	4.3	.13	.7	-.3	4.5
(5.3)[2]	VI					Antimony oxide	RLO	2.5	.24	1.0	+.4	2.5
4.5	VI	.11	.5	-.3	4.8	Lead-zinc, LZ_{25}	phen.	5.4	.08	.5	-.3	4.6
3.4	IX	.11	1.0	-.9	3.7	White lead	RLO (160° F.)	5.3	.07	.9	-.3	3.5
3.1	IX	.33	1.0	+.5	3.9	Titanium dioxide	RLO (160° F.)	4.4	.34	1.5	0	3.6
3.1	VI	.10	.7	-.6	4.2	White lead	RLO	4.8	.11	.8	-.3	3.9
2.5	VI	.16	.5	-.1	5.4	Titanium dioxide	phen.	1.9	.12	.4	-.1	4.2
2.2	VI	.20	.7	-.3	2.8	Antimony oxide	alkyd	2.4	.12	1.0	-.6	2.8
1.8	VI	.06	.2	0	4.7	White lead	phen.	1.5	.05	.5	-.3	4.4
(1.5)[2]	VI	(.25)[2]	(.6)[2]	(-.3)[2]	(4.0)[2]	No pigment	phen.	(1.5)[2]	(.16)[2]	(.8)[2]	(-.2)[2]	(3.4)[2]
.9	VI	.12	.4	-.2	4.9	Antimony oxide	phen.	.9	.11	.4	-.7	4.7
.8	VI	.27	.2	0	6.0	Antimony oxide	RLO	1.5	.25	.4	-.2	4.7
Average 4.7		.16	.6	-.3	4.5			3.9	.14	.7	-.3	4.0

[1] "RLO" means raw linseed oil; "BLO" means bodied linseed oil; "alkyd" means long-oil alkyd-resin varnish; "phen." means phenolic-resin varnish. The pigment volume was 0.30 except in the commercial "breather-type" paint. All films were formed (dried) at approximately 75° F. except those marked "(36° F.)" or "(160° F.)".

[2] Values in parentheses were not included in computation of the average values for the group.

[3] A trade-brand paint made with titanium dioxide, mica, and magnesium silicate in a vehicle of tung-oil varnish and bodied linseed oil; pigment volume 0.39.

[4] Not previously reported.

[5] A trade-brand paint made with titanium dioxide and magnesium silicate in a "copolymer" vehicle; pigment volume 0.30.

meability, water absorption generally was decreased proportionately much more than permeability. Thus for the most absorptive group, weathering lessened the average absorption from 73.9 to 20.7 per cent, whereas it only lessened the average permeability from 0.23 to 0.19. Among the unweathered pigmented latex films in Table 3, water absorption ranged from 7.0 to 75.9 per cent, well within the range for oil and oleoresinous paints, but permeability ranged from 1.44 to 6.45, far above the range of 0.06 to 0.54 for oil and oleoresinous paints. Weathering usually decreased the permeability of latex films proportionately much more than it did that of oil and oleoresinous films, but weathering was less effective in decreasing the absorption of latex than of oil or oleoresinous films. In fact, weathered latex films often absorbed more water after they were weathered than before. With some latex films, weathering increased water absorption while it decreased permeability.

All films absorbed moisture during the permeability test. The moisture absorption varied from 0.1 to 10.6 grams per 100 cubic centimeters of film. In general, those films that were high in water absorption in the soaking test were also relatively high in moisture absorption during the permeability test, although the parallelism between water absorption and moisture absorption was imperfect. Measurement of moisture absorption was purely incidental to the measurement of permeability. As a quantitative measure of moisture absorption, the method was crude and subject to much uncertainty because the films were exposed to damp air on one face and to dry air on the other face. Also, there was often a small but variable amount of condensed water on the damp face. More reliable measurements of the hygroscopicity of films of some oil paints were reported in paper II (5), from which it can be seen that the moisture absorbed during the permeability test was only a fraction of the absorption by similar films when both faces were exposed for three days to air at 97 per cent relative humidity. Thus a film of zinc oxide in linseed oil absorbed 15.8 grams of moisture per 100 cubic centimeters from air of 97 per cent relative humidity, but only 6.0 grams during the permeability test.

There was nearly always a slight change in the weight of the dry films during the permeability test. Among the unweathered films, 57 lost from 0.1 to 5.3 (only 4 of them over 1.9) grams per 100 cubic centimeters, 4 remained unchanged, and 1 gained 0.5 gram per 100 cubic centimeters. Among the weathered films, 43 lost from 0.1 to 2.3 grams per 100 cubic centimeters, 3 remained unchanged, and 11 gained from 0.1 to 0.6 gram per 100 cubic centimeters. Paint films, of course, generally lose weight steadily after they have passed the point of maximum weight soon after they have been formed. The small number of positive changes in weight observed may indicate that the downward course in weight may sometimes be interrupted by temporary additions of oxygen or combined moisture.

To study the characteristic effect of different pigments and of different vehicles on the specific permeability of films, parts of the data of Tables 2 and 3 were regrouped, certain aver-

Table 3.—SPECIFIC PERMEABILITY TO WATER VAPOR (AT 70° F.) OF FREE FILMS OF LATEX PAINTS, TABULATED IN ORDER OF DECREASING ABSORPTION OF WATER DURING 3-DAY SOAKING AS REPORTED IN PAPER VII OF THIS SERIES (5)

Unweathered films					Composition of film		Weathered films				
Water absorbed on soaking for 3 days A/V_o	Specific permeability: P_s	Moisture absorbed during permeability test	Change in: weight of: dry film during test	Thickness of film	Pigment	Latex vehicle[1]	Water absorbed on soaking for 3 days: A/V_o	Specific permeability: P_s	Moisture absorbed during permeability test	Change in: weight of: dry film during test	Thickness of film
Percent by volume	Mg. mm. per cm.^{2} per day	Gm. per 100 cc.	Gm. per 100 cc.	Mil			Percent by volume	Mg. mm. per cm.^{2} per day	Gm. per 100 cc.	Gm. per 100 cc.	Mil
GROUP WITH A/V_o MORE THAN 49 PERCENT											
75.9	5.96	1.6	-0.8	3.4	Commercial, TiO_2, silicates	PVA[2]	12.5	1.34	0.8	-0.5	0.1
(57.9)	(1.49)	(.6)	(-.5)	(3.1)	Commercial, TiO_2, silicates	PVA[2]					
(57.9)	(1.33)	(1.2)	(-.4)	(3.9)	No pigment	acrylic	(68.7)	(1.34)	(.4)	(+.2)	(0.4)
51.5	3.15	4.2	-.6	3.9	White lead	sty.-but. MC	15.0	1.12	2.9	-.9	0.7
50.5	6.03	.1	0	3.4	Zinc oxide	acrylic	42.5	5.40	.1	-1.5	0.2
49.7	5.49	.2	-.2	2.7	Zinc oxide	PVA	61.7	4.60	.3	-2.1	0.4
Average 56.9	5.16	1.5	-.4	3.3			32.9	3.61	1.0	-1.2	0.9
GROUP WITH A/V_o BETWEEN 20 AND 49 PERCENT											
30.2	2.42	1.1	-.1	4.8	Magnesium silicate	acrylic	11.9	.62	.4	+.1	0.3
27.7	3.05	2.8	-.4	4.4	Zinc oxide	sty.-but. MC	23.7	.94	.7	-.7	1.7
23.0	3.29	.7	-.9	4.8	Titanium dioxide	PVA	15.0	1.84	.2	+.2	0.4
22.7	1.44	1.8	-.4	4.9	White lead	acrylic	47.2	.53	1.5	-.1	0.3
20.6	3.80	1.7	-.2	3.8	Magnesium silicate	sty.-but. MC	8.1	.42	.6	+.4	1.5
20.4	4.57	1.2	-.1	5.2	Zinc oxide	sty.-but.	18.7	.25	3.6	-.9	1.8
Average 24.1	3.09	1.5	-.3	4.6			38.6	.77	1.2	-.2	0.9
GROUP WITH A/V_o BETWEEN 10 AND 20 PERCENT											
15.3	3.92	1.2	-.6	3.7	Titanium dioxide	sty.-but. MC	5.9	.13	1.9	-.7	3.6
13.3	6.45	.7	-1.5	5.8	Magnesium silicate	sty.-but.	10.6	.21	.9	+.2	1.4
11.9	6.08	2.0	-.2	7.3	White lead	sty.-but.	16.7	.05	5.4	-1.1	2.1
10.9	5.23	1.1	-.2	5.0	Titanium dioxide	sty.-but.	15.2	1.03	1.4	-.3	1.0
Average 12.8	5.42	1.2	-.6	5.4			12.1	.35	2.4	-.5	1.9
GROUP WITH A/V_o LESS THAN 10 PERCENT											
8.9	2.39	2.5	-2.5	4.4	Magnesium silicate	PVA	18.2	1.12	.4	+.4	0.2
(8.7)	(6.77)	(6.9)	(-5.3)	(5.4)	No pigment	sty.-but	Styrene-butadiene films were destroyed by cracking weathering				
(8.2)	(2.34)	(1.0)	(-2.1)	(4.0)	No pigment	PVA	48.9	1.33	.7	+.6	2.5
7.0	3.87	.7	-.2	4.7	Titanium dioxide	acrylic	6.5	1.61	.3	+.1	0.2
Average 7.9	3.13	1.6	-1.3	4.5			12.3	1.35	.3	+.2	0.2

[1] Trade brand latexes were used. "Acrylic" means a polyacrylic latex; "PVA" polyvinyl acetate; "sty.-but." a styrene-butadiene; "sty.-but. MC" a styrene-butadiene latex with addition of methyl cellulose.

[2] A trade-brand PVA latex paint.

[3] Values in parentheses were not included in computation of the average values for the group.

[4] The same trade-brand paint the unweathered film of which was leached in water and redried before testing. The absorption of water by the leached film was not measured quantitatively but was observed qualitatively to be much less than that of the unleached film.

age values computed, and the results recorded in Table 4. Thus in the first line of Table 4 are reported the average permeability and average water absorption of the four unweathered films and the four weathered films of the white lead paints made with the raw linseed oil, bodied linseed oil, alkyd-resin varnish, and phenolic-resin varnish vehicles. In the eighth line of Table 4 are reported the average permeability and average water absorption of five unweathered and five weathered films with phenolic-resin varnish pigmented with white lead, titanium dioxide, zinc oxide, lead-zinc, and titanium zinc.

In oil and oleoresinous vehicles, white lead and zinc oxide made films of lower specific permeability than corresponding films with antimony oxide, magnesium silicate, or titanium dioxide. White lead and zinc oxide are chemically basic and capable of reaction with free fatty acids or acid decomposition products in paint films, whereas the other pigments are unreactive in this sense. White lead made less permeable films than zinc oxide. The pigments had very different effects on water absorption. Thus white lead caused low absorption as well as low permeability, but zinc oxide caused highest absorption despite relatively low permeability. Antimony oxide, which produced lowest absorption, stood high in permeability.

In latex vehicles, pigments had relatively less effect on permeability than they did in oil and oleoresinous vehicles. White lead, magnesium silicate, and titanium dioxide stood in the same relative order, but zinc oxide was out of line in that it gave higher permeability than any other pigment in latex vehicles. In water absorption by latex films, white lead failed to take the low relative position it did among oil and oleoresinous films.

Among oil and oleoresinous vehicles, phenolic-resin varnish made the least permeable and raw linseed oil the most permeable paint films. Bodied linseed oil and alkyd-resin varnish made films of intermediate and about equal permeability. Phenolic-resin films were also lowest in water absorption, whereas bodied linseed oil was intermediate, and alkyd resin and raw linseed oil were relatively high. The unpigmented oil and oleoresinous vehicles (recorded in Table 2 but not in Table 4) made clear films that were more permeable than the pigmented films with the same vehicles, but in water absorption the clear films were intermediate among the pigmented films with the same vehicles.

Among latex vehicles, styrene-butadiene made pigmented films that, before weathering, were on the average more permeable but less absorptive of water than the pigmented films of the other latexes. The unweathered pigmented films with the other latexes did not differ significantly in either permeability or water absorption. Pigmented films of styrene-butadiene and of styrene-butadiene with methyl cellulose became much less permeable after they were weathered, so much so that they were little higher in permeability than some oil paints. On the other hand, weathering decreased the permeability of pigmented polyacrylate and polyvinyl acetate films only moderately, and they remained far more permeable than any oil paints. Weathering tended to increase the water absorption of the latex films except those made of styrene-butadiene with methyl cellulose, for which the absorption decreased after weathering.

Unpigmented films of polyacrylate and polyvinyl acetate were less permeable before weathering than any of the pigmented films of the same latex, and after weathering were less permeable than corresponding films pigmented with titanium dioxide or zinc oxide. Such behavior stands in strong contrast with that of the clear and pigmented films with oil and oleoresinous vehicles. The unpigmented film of styrene-butadiene was somewhat more permeable than any of its pigmented films, but the unpigmented film could not be tested after weathering because

Table 4.—SPECIFIC PERMEABILITY AND WATER ABSORPTION AS AFFECTED BY PIGMENT AND VEHICLE INGREDIENTS OF FILMS

Pigment or vehicle ingredient considered	Kind and number of vehicle or pigment ingredients averaged	Specific permeability, P_s: Unweathered films	Specific permeability, P_s: Weathered films	Water absorption, A/V_o: Unweathered films	Water absorption, A/V_o: Weathered films
		Mg. mm. per cm^2 per day		Percent by volume	
Pigments:					
White lead, L	oil and oleoresinous (4)	0.10	0.08	5.9	5.1
Lead-zinc, LZ_{25}	oil and oleoresinous (4)	.14	.09	31.0	13.8
Zinc oxide, Z	oil and oleoresinous (4)	.18	.17	46.7	16.4
Titanium-zinc, TZ_{25}	oil and oleoresinous (4)	.19	.13	44.6	13.5
Antimony oxide, A	oil and oleoresinous (4)	.20	.18	2.3	1.8
Magnesium silicate, X	oil and oleoresinous (4)	.24	.25	34.9	11.4
Titanium dioxide, T	oil and oleoresinous (4)	.28	.18	13.1	4.4
Oil and oleoresinous vehicles					
Phenolic-resin varnish	L, T, Z, LZ_{25}, TZ_{25} (5)	.13	.10	5.0	3.7
Bodied linseed oil	L, T, Z, LZ_{25}, TZ_{25} (5)	.17	.16	16.3	10.9
Alkyd-resin varnish	L, T, Z, LZ_{25}, TZ_{25} (5)	.17	.12	49.6	13.2
Raw linseed oil	L, T, Z, LZ_{25}, TZ_{25} (5)	.25	.22	42.2	15.5
Pigments:					
White lead, L	latex vehicles (3)	3.56	.57	28.7	26.3
Magnesium silicate, X	latex vehicles (4)	3.76	.59	18.2	39.0
Titanium dioxide, T	latex vehicles (4)	4.08	1.15	14.0	10.6
Zinc oxide, Z	latex vehicles (4)	4.78	3.30	37.1	36.6
Latex vehicles:					
Polyacrylic resin	L, T, Z, X (4)	3.44	2.04	27.6	53.8
Styrene-butadiene and methyl cellulose	L, T, Z, X (4)	3.48	.65	28.8	13.2
Polyvinyl acetate	T, Z, X (3)	3.72	3.18	27.2	31.6
Styrene-butadiene	L, T, Z, X (4)	5.58	.39	14.1	15.3

it failed to remain intact. The high permeability of the latex vehicles when compared with oil and oleoresinous vehicles, together with the differences in relative permeability of unpigmented and pigmented films and the generally low swelling efficiency of latex paints, even before weathering, that was pointed out in paper VII (5), all suggest that the permeability of latex depends largely on a condition of porosity caused by failure of the droplets of emulsified polymers to coalesce to form a continuous matrix (9). This condition is absent in oil and oleoresinous films. It should be noted, however, that latex paints of low permeability comparable with oil paints are said to be obtainable by special formulation with suitable pigments (14).

Variation of Permeability with Temperature

Further information about the nature of the permeability of paint films was obtained by studying the effect of temperature on the permeability of films of 12 paints. The equation given previously for specific permeability, P_s, as customarily used by paint technologists applies at only one temperature, at which the vapor pressures on the two faces of the film differ always by the same amount. A more general relation for a permeability constant, *P*, is

$$P = \frac{ml}{qtp}$$

in which *m* is the mass of water vapor in grams that passes through a film of thickness *l* in centimeters and area *q* in square centimeters during time *t* in hours under a difference in vapor pressure of *p* in centimeters of mercury (6, 7, 11, 13, 24, 29, 32, 33). (Choice of units of measurement varies among the workers.) If the vapor pressure over calcium chloride is considered zero, *p* may be taken as the vapor pressure of water at the temperature of measurement, and then:

at 38° F., $P = 72.3 \times 10^{-7} P_s$
at 70° F., $P = 22.3 \times 10^{-7} P_s$
at 156° F., $P = 1.88 \times 10^{-7} P_s$

If the permeability constant is inversely proportional to the thickness of film and directly proportional to the difference in vapor pressure, the relation between permeability constant and temperature is

$$P = P_o e^{-E/RT}$$

in which P_o is the permeability constant independent of temperature, *E* is an activation energy, *R* is the gas constant, *T* is the absolute temperature, and *e* is the base of natural logarithms. The logarithm of *P* should then be proportional to *1/T* (6, 7, 11, 24, 32).

Films of 12 paints and clear vehicles reported in Tables 2 and 3 were selected for measurement of permeability at different temperatures. The permeability of each film was determined first at 38° F., then at 70° F., and finally at 156° F. Specific permeability was converted to a permeability constant by the equations cited. The results appear in Fig. 1, in which *P* is plotted on a logarithmic scale against *1/T*.

The logarithm of the permeability constant was linearly related to *1/T* for all films tested. The constant was much larger for latex films than for oil and oleoresinous films, although at 156° F. ($1/T = 2.9 \times 10^{-3}$) the largest constant for an oil film was nearly as large as the smallest constant for a latex film. The 12 constants spread over a much wider range at 38° F. ($1/T = 3.6 \times 10^{-3}$) than at 156° F.

For six of the eight oil or oleoresinous films, the slope of the line relating *log P* to *1/T* was negative, which indicates that the activation energy was greater at high than at low temperature. Such negative slope has generally been reported in the literature on permeability of films of plastics and paints to water vapor and gases. But for two oil or oleoresinous paints, white lead in alkyd resin and weathered white lead in raw linseed oil (lines 6 and 8 in Fig. 1), and for all four latex films studied, the slope of *log P* versus *1/T* was positive. It therefore appears possible for the activation energy to be greater at low than at high temperature. Positive slope is not peculiar to white lead, raw linseed oil, the alkyd resin, or weathered films, because negative slopes were observed for unweathered white lead in raw linseed oil and for weathered lead-zinc in alkyd resin. Positive slope, however, may be characteristic of latex films.

The permeability constant is further related to the diffusion constant, *D*, and the solubility of water vapor in the film, *S*, by the relation $P = DS$. The activation energy is the sum of the activation energy for diffusion and the heat of solution of water vapor in the film. Since a decrease in diffusion with increase in temperature is highly improbable, the positive slope of *log P* versus *1/T* for latex and some oil films suggests that the solubility of water vapor in such films decreases with rising temperature. Experimental data to test the suggestion are not yet available.

It should be pointed out that water vapor passed through all films more rapidly at 156° F. than at 38° F., whether the permeability constant increased or decreased. Thus for the film of titanium dioxide in polyacrylic latex (line 12 in Fig. 1), for which *log P* fell off most rapidly with rising temperature, the Payne specific permeability, P_s, was 29.1 at 156° F. and only 2.16 at 38° F.

The Payne-cup method was chosen for the measurements of permeability because much of the published data for paint films has been obtained by that method. The method is attractive for its convenience, but it is open to possible objections, especially for determinations at other than room temperature. Once the cup has been closed with a film that is impenetrable by air under a pressure gradient, there can be no movement of air in or out of the cup to offset the change in volume of enclosed air when the temperature is altered or when moisture vapor escapes through the film. Flexible films are then stretched, and their exposed area is increased by the difference between the internal and external pressures. On the other hand, if the film is penetrable by air under a pressure gradient, there may also be loss of moisture vapor by penetration in addition to the loss by permeation. Moreover, poor circulation of air inside and outside the cup may result in pressure of moisture vapor somewhat below saturation at the film interface within the cup and greater than zero at the film interface outside the cup. Thus it is desirable to test further the relations between the temperature coefficient of the permeability constant and the absolute temperature by some method that is less open to objection than the Payne cup.

More recent tests have shown that the logarithm of the permeability constant may not always be related linearly to the reciprocal of the absolute temperature. Chips of paint from the Washington Mansion at Mount Vernon, Virginia, gave permeability constants of 8.8×10^{-7} at 36° F., 29.0×10^{-7} at 70° F., and 36.1×10^{-7} at 156° F. The constant at 36° was much too low to comply with a linear relation. The chips were 73 to 110 mils thick, and were made up of white paint containing sand to produce a rough surface. The paint was applied in about 20 paintings from 1775 to 1956.

Penetration by Air under Pressure Difference

The term breathing properly applies to a movement of air into or out of a discretely porous or cellular body such as the lungs under a difference of pressure. Gardner (12) apparently so intended, when he introduced the term, to distinguish some paint films

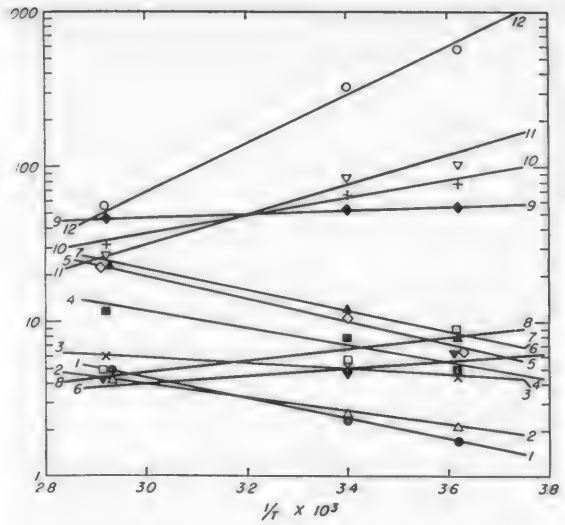

Fig. 1.—Permeability constant, P, plotted on a logarithmic scale as a function of the reciprocal of the absolute temperature for films numbered as follows: 1. Lead-zinc in alkyd resin, weathered; 2. White lead in bodied linseed oil; 3. White lead in raw linseed oil; 4. Zinc oxide in raw linseed oil; 5. Bodied linseed oil without pigment; 6. White lead in alkyd resin; 7. Titanium dioxide in raw linseed oil; 8. White lead in raw linseed oil, weathered; 9. Polyvinyl acetate latex without pigment; 10. Titanium dioxide in styrene-butadiene latex; 11. White lead in styrene-butadiene latex; 12. Titanium dioxide in acrylic latex.

Table 5.—PENETRATION OF FILMS OF OIL PAINTS BY AIR UNDER A PRESSURE GRADIENT

Composition of oil-containing film	Pigment volume of film	Rate of passage of air under 0.38 atmosphere difference of pressure through 3.14 square centimeters of: Unweathered film Cc. per min.	Weathered film Cc. per min.
Commercial "breather-type" paint	0.39	0	0.6
Commercial "blister-resistant" paint	.30	0	----
Raw linseed oil paints pigmented with:			
Basic carbonate white lead	.60	0	0
Basic carbonate white lead	.30	0	0
Zinc oxide	.60	5.3	----
Zinc oxide	.55	.6	----
Zinc oxide	.30	0	.25
Titanium dioxide	.60	21.9	----
Titanium dioxide	.55	13.3	----
Titanium dioxide	.50	0	3.7
Titanium dioxide	.45	----	11.3
Titanium dioxide	.30	0	0
Magnesium silicate	.30	0	0

Table 6.—PENETRATION OF FILMS OF LATEX PAINTS BY AIR UNDER A PRESSURE GRADIENT

Composition of latex-containing film	Rate of passage of air under 0.38 atmosphere difference of pressure through 3.14 square centimeters of: Unweathered film Cc. per min.	Weathered film Cc. per min.
Commercial polyvinyl acetate paint	0	0
Polyvinyl acetate latex with:		
No pigment	0	0
Zinc oxide	1800 F*	2000 F
Titanium dioxide	0 F	0 F
Magnesium silicate	0 F	0 F
Polyacrylate latex with:		
No pigment	0	64 F
White lead	0 F	78 F
Zinc oxide	1500 F	1900 F
Titanium dioxide	0	1
Magnesium silicate	0	0
Styrene-butadiene latex with:		
No pigment	0	
White lead	0	230
Zinc oxide	0	[illegible]
Titanium dioxide	46 F	1600 F
Magnesium silicate	0	[illegible]
Styrene-butadiene latex with methyl cellulose and:		
White lead	0 F	920 F
Zinc oxide	1	65
Titanium dioxide	0 F	0
Magnesium silicate	0	0

*The symbol F indicates films that could be seen to contain small vacuoles caused by retention of foam after the wet film hardened.

from others. All breathing paint films should therefore be readily penetrated by air, but not all films should breathe, even though all paint films tested so far are permeable to water vapor in at least some degree. It was therefore of interest to learn whether ordinary paint films let air pass through under a pressure gradient, and if not, whether there are paint films that do.

A suitable device for the purpose was made with an Asbeck–Van Loo critical pigment volume cell (1). The cell consists of two bell-shaped parts of glass, the wide portions of which fit together in a ground-glass joint. The bottom part, which forms the male piece of the joint, is closed by a fritted glass disk set flush with the glass rim. The narrow portion of each part ends in an outlet tube. The outlet of the male part was inserted through a rubber stopper in the mouth of a 1-liter filter flask, the side arm of which was connected through a stopcock to a water aspirator for suction. An open-arm mercury manometer was provided to measure the pressure of air in the filter flask. There was also a bleeder tube with stopcock to admit air for precise adjustment of suction at the beginning of a test, prompt release of suction after a test, and admission of air when calibrating the apparatus. The total volume of air at atmospheric pressure contained within the apparatus between the surface of the fritted glass disk and the aspirator stopcock was 1290 cubic centimeters.

A circular sample of paint film to be tested was cut exactly to the diameter of the fritted glass disk. A ring made of a short piece of copper tubing 2 centimeters in diameter inside was centered over the film. A rim of molten paraffin was then formed between the outer surface of the copper ring and the glass rim of the cell and allowed to harden. Thus only the portion of the paint film enclosed within the copper ring was exposed for possible penetration by air. The female part of the cell was then placed in position over the sample, and its outlet tube was closed by a short piece of rubber tubing and pinchcock.

Air was evacuated from the apparatus and the suction was adjusted through the bleeder tube until the manometer registered —28.9 centimeters of mercury, a pressure difference of approximately 0.38 atmosphere. A constant level in the manometer for five minutes indicated that the apparatus was free from leaks. The pinchcock at the outlet of the female part of the cell was then removed, and a stop-watch was set in motion at the same time. If the paint film permitted air to pass, the manometer reading was recorded when exactly five minutes had elapsed. Impenetrable films, of course, permitted no change in manometer reading. If a film was so porous that the pressure rose to —7.9 centimeters of mercury within five minutes, the time required for pressure to rise from —28.9 to —7.9 was recorded, and several successive tests of the film were made.

To permit computation of the rate of passage of air through the films, the apparatus was calibrated as follows: The fritted glass disk was sealed with a disk of paper entirely covered by a layer of paraffin. The system was evacuated to a manometer reading of —28.9 centimeters of mercury. Successive volumes of approximately 50 cubic centimeters, accurately measured in a gas burette, were admitted through the bleeder tube, and the manometer reading was recorded after each admission until the manometer reached —7.9 centimeters of mercury. A cali-

bration curve was then drawn to relate manometer readings to volume of air at atmospheric pressure.

When the fritted glas disk was left open, air passed through it at the rate of 3320 cubic centimeters a minute. When an impenetrable paint film was perforated five times with the point of a common pin and then tested, it allowed 321 cubic centimeters of air to pass a minute.

Table 5 reports the results obtained with some oil paints. A commercial "breather-type" paint, said to resist blistering because it is porous enough to breathe, allowed no air to pass through its unweathered film and only 0.6 cubic centimeters a minute through its weathered film. Its specific permeability to water vapor (Table 2) was also very low. Such paint cannot properly be said to breathe, although it may well be reasonably resistant to moisture blistering. Another commercial paint said to resist blistering but not claimed to breathe allowed no air to pass and was also very low in specific permeability to water vapor (Table 2).

Single-pigment paints made with raw linseed oil and white lead, zinc oxide, titanium dioxide, or magnesium silicate at 0.30 pigment volume, which is within the range of pigment volume customary for house paints, allowed no air to pass through their unweathered films. The weathered films were also impenetrable or, in the case of the weathered zinc oxide film, very nearly so. Unweathered films porous enough to pass air, however, were made with zinc oxide and with titanium dioxide by raising the pigment volume to a point far above that practicable for house paints. Thus the zinc oxide paint film at 0.55 pigment volume passed 0.6 cubic centimeters of air a minute, and at 0.60 pigment volume it passed 5.3 cubic centimeters a minute. The titanium dioxide paint film at 0.55 pigment volume passed 13.3 and at 0.60 pigment volume 21.9 cubic centimeters a minute. Films of white lead paint, weathered or unweathered, were impenetrable even at 0.60 pigment volume. The critical pigment volume, the point above which there is no longer enough linseed oil to fill all the spaces between particles of pigment in the dried films (1, 3, 10, 27), was shown in paper IV (5) to lie between 0.55 and 0.60 for white lead paint, 0.45 and 0.50 for zinc oxide paint, and 0.40 and 0.45 for titanium dioxide paint. It may be concluded, therefore, that films of oil paints breathe in the sense of becoming penetrable by air under a pressure gradient when the paints are made at a pigment volume somewhat above the critical. The data of Table 5 suggest further that weathering tends to develop penetrability to air in some films that before weathering were impenetrable. Sufficient weathering to cause paint films to crack renders them readily penetrable to air, of course.

Results with films of latex paints are reported in Table 6. Most of the unweathered films and 8 of the 18 weathered films allowed no air to pass. Four unweathered and 10 weathered films were penetrated by air. Two unweathered and four weathered films were porous enough to let through 920 to 2000 cubic centimeters a minute. Penetrable weathered films always passed more air than their unweathered counterparts. Neither the composition of the latex nor the kind of pigment seems to govern penetrability, because both penetrable and impenetrable films were obtained with each kind of latex and with each pigment.

The behavior of latex paints in tests of permeability to water vapor and their low swelling efficiency when soaked in water were attributed to porosity caused by failure of droplets of emulsion to coalesce completely when the films harden. Such porosity evidently need not render the films penetrable by air if the pores are not connected with one another. Penetrability by air may require larger pores that join together to afford continuous passageway.

Clearly, water vapor permeates most paint films by some mechanism other than passage through interconnected pores, because penetration by air under a pressure gradient and permeability to water vapor are not at all parallel. Fifteen unweathered latex films that were impenetrable by air ranged in specific permeability to water vapor from 1.33 to 6.77 (Table 3), compared with a range of 0.07 to 0.45 (raw linseed oil without pigment 1.39) for films of oil paint (Table 2). Latex films through which air passed at 1500 or 1800 cubic centimeters a minute were lower in specific permeability to water vapor than some of the latex films through which no air passed. Weathering rendered penetrable some latex films that were impenetrable to air before weathering, and increased the penetrability of those latex films that were previously penetrable. Weathering often had the opposite effect on specific permeability to water vapor, however. Thus, for example, when films of titanium dioxide in styrene-butadiene latex were weathered, penetrability increased 46 to 1600 cubic centimeters of air a minute, but specific permeability to water vapor decreased from 5.23 to 1.03.

Latex paints have a notable tendency to retain foam unless they are made with effective anti-foaming agents. Such agents were not used in the latex paints made in the laboratory. The latex films that were tested for penetration by air were therefore examined by transmitted light under a microscope. Some of the films (indicated in Table 6) contained easily observable vacuoles that presumably were left by foam in the wet paint after the film hardened. Some vacuoles clearly afforded passage from one side of the film to the other. Others apparently were completely enclosed within the film. Most of the penetrability of latex films to air may therefore be attributed to open pores left by foamy paint. There were some films with vacuoles that were impenetrable, however, and some apparently free from vacuoles that were penetrable, especially the weathered film of white lead in styrene-butadiene latex that passed 230 cubic centimeters of air a minute. But permeability of the films to water vapor apparently was unrelated to the presence of vacuoles, because the eight unweathered latex films with observable vacuoles ranged in specific permeability from 1.44 to 6.03 (average 3.87), whereas the 11 films without observable vacuoles ranged from 1.33 to 6.77 (average 4.24).

Most films that were penetrable to air could be tested repeatedly with concordant results, which indicates that the films were unaltered by the pressure gradient of 0.38 atmosphere during test. Four weathered films of latex paints, three with and one without observable vacuoles, were exceptions. With the film of white lead in polyacrylic latex, five successive tests of air penetrability gave rates of 78, 96, 118, 123, and 145 cubic centimeters a minute, respectively. Such increasing penetrability might be attributed to repeated fracturing of the walls of vacuoles under stress exerted by the pressure gradient on a film rigid enough to resist compression. But the other three exceptional films exhibited a reverse behavior, a decrease in penetrability with each successive test. The weathered film of unpigmented polyacrylic latex gave successive rates of penetration of 64, 45, and 36 cubic centimeters of air a minute, the weathered film of zinc oxide in styrene-butadiene latex containing methyl cellulose gave successive rates of 65, 56, 54, 52, and 51 cubic centimeters a minute, and the weathered film of white lead in styrene-butadiene latex which contained no observable vacuoles, gave successive rates of 230 and 90 cubic centimeters a minute. Decrease in penetrability in successive tests may indicate that the film becomes permanently compressed, so the effective cross section of its po

becomes diminished by application of pressure.

Conclusions

1. The penetration of water through coatings of oil paints can be observed by application of the coatings over a thin layer of blue cobalt chloride in methyl cellulose on clean glass. The coatings may then be weathered before testing by exposure to artificial sunlight (without spraying with water). Tests are made by immersing the coated specimens in water and observing the time required for the cobalt chloride to change from blue to pink and for the coating to become blistered.

2. Penetration of water occurs earlier in some portions of a given coating than in others. First penetration through unweathered coatings was observed in 2 to 13 hours, but penetration was completed only after 9 to 48 hours. The "wet line" advancing through a coating evidently is of very irregular depth, which suggests a heterogeneous film structure. Although longer time is required in general for water to penetrate thick than thin coatings of a given paint, the relation between time and thickness is not sharply defined, as might be expected from the observed irregularity in penetration. Blistering does not occur until penetration is well advanced, but may occur before penetration is complete.

3. Penetration occurs faster in coatings of high water absorption, such as zinc oxide paint, than in coatings of low absorption, such as white lead paint. Weathered coatings are usually penetrated more rapidly and blistered sooner than are unweathered coatings of similar paint. The relations between time of penetration and thickness of coating and between penetration and water absorption are also more obscure.

4. The mechanism of blistering in these tests is largely osmotic, because the blistering occurs much sooner where the water-soluble cobalt chloride and methyl cellulose are interposed between coating and glass than elsewhere.

5. Measurements of the specific permeability of paint films to water vapor (Payne cup method at 70° F.) revealed that permeability and water absorption bear little or no relation to each other. Both high and low permeabilities were found among highly absorptive films and also among films of low absorption. As groups, oil and oleoresinous paint films are very much less permeable to water vapor than are latex paints, yet the range in water absorption of the latex paints falls within the range for oil and oleoresinous paints. If water absorption affords an indication of the resistance of a paint to moisture blistering, permeability to water vapor does not, at least within the range of permeabilities of the oil and oleoresinous paints.

6. During permeability tests in Payne cups, paint films absorbed much less moisture than when they were soaked in water. The amounts were roughly parallel, however. Such absorption in Payne cups may be high when the permeability is low, and may be low when the permeability is relatively high.

7. In oil and oleoresinous vehicles, both white lead and zinc oxide make paint films of lower permeability than is obtained with titanium dioxide, antimony oxide, or magnesium silicate. White lead and antimony oxide impart low water absorption, however, whereas zinc oxide imparts very high water absorption. In latex vehicles, permeability is high with any of these pigments, and both white lead and zinc oxide tend to cause higher water absorption than titanium dioxide or magnesium silicate. Among the vehicles tested, phenolic-resin varnish made paint films that were usually low in both permeability and water absorption. Raw linseed oil vehicle favored high permeability and high absorption, bodied linseed oil held an intermediate position for both permeability and absorption, and alkyd-resin vehicle developed intermediate permeability but even greater absorption than raw linseed oil.

8. The specific permeability of all paint films increases rapidly with temperature. Study of films of 12 paints, however, showed that the logarithm of the permeability constant, which considers differences in vapor pressure, is linearly related to the reciprocal of the absolute temperature, which is to be expected of films that are not too hydrophilic and do not swell too much. Latex films differ strikingly from most oil or oleoresinous films in that their permeability constant is not only much higher, but also decreases as temperature rises. There were two oil paints, however, for which the permeability constant decreased with rising temperature. For such films, the solubility of water vapor in the film probably falls as temperature rises.

9. A device was constructed, based on an Asbeck-Van Loo cell for measurement of critical pigment volume, to study the ability of paint films to "breathe" in the sense of permitting air to pass through under a pressure difference of 0.38 atmosphere. Films of linseed oil paints within the range of pigment volume practicable for house paints are incapable of such breathing. Films that can be penetrated by air under a pressure gradient can be made with pigment volumes well above the critical pigment volume. A commercial "breather-type" paint was found to be impenetrable by air until its film had been weathered. Impenetrable films may become porous enough to breathe after they have been weathered, but some paint films remain impenetrable after 15 days of artificial weathering. Films of latex paints made at pigment volumes suitable for exterior use are impenetrable, or nearly so, provided that the films are free from vacuoles left when foamy paint hardens. Vacuoles may make the films penetrable or leave them still impenetrable, depending on whether the vacuoles are connected with one another or remain isolated.

10. The permeability of paint films to water vapor is not governed by the presence of pores through which air can pass under a pressure gradient. Films highly permeable to water vapor may be entirely impenetrable by air. On the other hand, latex films of very high penetrability by air because of vacuoles may be no more permeable to water vapor than other latex films that are impenetrable to air.

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Endless Bed Sander Feeds

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THE ENDLESS BED of a competent modern drum sander might be considered as a special flat-topped conveyor, designed so that its top surface travels in a carefully governed plane. The plane in which the top surface of the bed travels is perfectly parallel with the axes of the different sanding drums, when the setting is correct, insuring that work will be sanded to uniform thickness throughout its width. An endless bed designed for this purpose must be built so that full control can be exercised over its travel, and true accuracy obtained.

Some of the better endless-bed sanders incorporate heavy steel slats. On these slats are mounted the necessary steel-reinforced rubber cushions. The slats are designed on an edge-telescoping principle to keep them dust-tight. They are mounted on heavy drop-forged steel links which form the traveling chains. The heavy chain links are equipped with oil-retaining bronze bearings where they join to insure proper lubrication. Connecting pins of alloy steel used for the chain links successfully withstand wear over a long period.

Chain sprockets at the infeed end of the machine are provided with an adjustment, so a proper degree of bed-chain tightness may be maintained. Nevertheless, the chains do not directly support the endless-bed slats, so far as holding them in a plane is concerned. To control their travel with reference to a plane, they are supported by and travel on semi-steel milled and polished cast bed-ways. Forced-feed lubrication is used in connection with these ways, to insure a continual supply of oil.

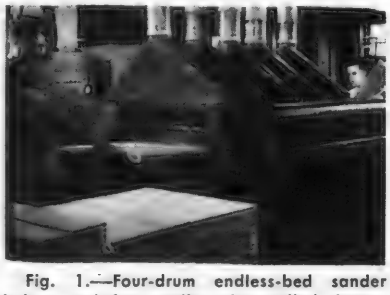

Fig. 1.—Four-drum endless-bed sander being used for sanding dove-tailed drawer fronts at Kroehler Mfg. Co., Kankakee, Ill. The internal angle between infeed end of the bed and the machine frame is location of force-feed lubricator. In this position, it takes its power directly from the bed-operating mechanism. Photo courtesy Solem Machine Co., Rockford, Ill.

One advantage of an endless bed, running as described, is that it provides forward traction to short pieces at practically every point. Therefore, the endless-bed type of machine is particularly desirable in furniture factories, millwork plants, etc., where many relatively short workpieces enter into construction of different products. Incidentally, many workpieces require sanding on one side only, so that a single pass through the machine is sufficient.

New Developments in Woodworking Machinery[1]

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Cites the need for an equipment replacement program in woodworking plants. New machinery developments which will improve quality and increase production are discussed. Factors are listed which should be considered when purchasing new or replacing equipment.

Introduction

ONE OF AMERICA'S FOREMOST scientific engineers, Charles Kettering, has stated on numerous occasions that if you are doing today what you did ten years ago, you are doing it wrong, and he may well have added —very expensively.

In the vast majority of woodworking plants, no equipment replacement program is maintained. Equipment is replaced only when the outdated machine breathes its last and falls in pieces to the mill floor.

In our highly competitive market, someone must pay for the high operational and, in particular, maintenance costs of worn-out and out-of-date equipment. To cope with closely figured prices and still use yesterday's methods, some sacrifice must be made. If it is in workmanship and material, the customer pays. If the manufacturer tries to maintain quality, he must sacrifice profit. Either way, it indicates that a thorough study of modern equipment and production methods, by management and key personnel is long overdue.

Far too often, replacement is purchased on a strict price basis, without any study to secure a machinery replacement which will increase output, quality and, in many cases, reduce manpower. In some instances, perhaps the function that was performed by the machine being replaced could well be obsolete or perhaps combined with another operation performed on a new machine.

Trained and experienced salesmen of the established woodworking machinery manufacturers and distributors should have the necessary knowledge to be of assistance to you, in providing the best machine for the production, quality, and type of work you require. In Canada, and to a lesser degree in the United States, little or no effort is made by furniture manufacturers to even request this information. Surely, when a vast amount of information, plans, and production figures are available, based on actual operation, it is only good business to take advantage of any assistance which may be provided.

Few manufacturers in the furniture industry in Canada seem to realize that the extra cost of operating with obsolete and worn-out equipment will more than pay for its replacement. In actual fact, you are paying for modern equipment in high production costs, but getting none of its benefits.

In planning replacement in the furniture industry, there is only one logical place to start. What good is it to spend $40,000 or $50,000 on a finishing room, when the kiln capacity will only take care of half of the production?

New Developments

Lumber Stackers: The handling of lumber from car or truck to yard and kiln is expensive by the methods employed so far in Canada. In many cases, handling costs run $2 to $3 per 1,000 feet. In the Southern U. S., where many up-to-date furniture plants are now operating, the introduction of yard and kiln car package stacks, sometimes combined with grading arrangements, has lowered this cost at least 50 per cent. In many cases, the cost of stickered packages per 1,000 feet is below 50¢. In addition, the machines perform this task far better than even the best hand stacking and are completely versatile as to type of stacking to be done.

Kilns: The most important single factor in good furniture is stock properly dried. This, in many cases, is not so apparent until after the furniture has been shipped and the returned freight bill crosses the manager's or owner's desk. A high speed, high temperature dry kiln is now being produced commercially. The smaller type capacity kiln is reported to have faster turnover and cut down inventory and costs.

Break-out department: A good swing cut-off operator will probably handle about 2,500 board feet per shift. An operator with either a hydraulic, mechanical, or air-operated automatic cut-off saw will handle up to 7,000 board feet at peak times. By installing a lift, linking conveyors, and modern equipment, it is possible to increase production 100 per cent, with 50 per cent less labor and produce a

Fig. 1.—Lawson lumber stacker can help reduce material handling costs.

[1] Presented at annual meeting, FPRS Eastern Canadian Section, March 1-2, 1956, in Toronto, Ont.

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Fig. 2.—Conveyorized breakout saw increases production and reduces costs.

Fig. 3.—Electronic edge bonder will produce up to 10,000 square feet of panels per day with two operators.

better product. Facer planer and single surfacer, edge jointer, and rip saws operating as a team can slash costs to an amazing degree. In actual fact, the linkage of the equipment can be varied so that any sequence of operation can be performed.

Some 85 combination facers and planers, known in the trade as Strait-o-planers, have been installed in American furniture plants within the last 18 months. This machine, although costing about the same as a facer and single surfacer, cuts down floor space and eliminates a conveyor.

Solid core and panel-on-frame gluing: Quite a few Canadian plants have high frequency core gluers and dielectric high frequency panel-on-frame presses. A good electronic edge gluer will produce up to 10,000 square feet of panels per day with two operators, at curing cycles ranging up to 1½ minutes. It must be kept in mind, however, that due to the types of electrical field used, a core gluer is not suited for panel-on-frame or vice versa. The same generator, however, can be used.

In a study undertaken in the United States, the average production per man, using a clamp carrier, was shown to be approximately 2,000 square feet per day. The savings accruing from either edge bonding or panel-on-frame construction are so apparent in production that this is one operation on which there can be little difference of opinion.

Veneer press, splicer and jointer: The introduction, since World War II, to United States and Canada of the single-end two-opening hot plate press has brought all of the advantages of hot-plate pressing to the smaller manufacturer. A time study will show conclusive evidence that the loading and unloading of the press consumes the largest part of the overall press cycle. Consequently, development of automatic loading and unloading tables was undertaken, and these now can be supplied to give high production on single or two-deck presses. A two-opening 100-inch x 50-inch press, equipped with automatic loading tables, will outproduce a ten-opening multi-deck hand-fed unit.

The tapeless splicer will, in tape and sanding costs to remove the tape, pay for itself in about 18 months, without any consideration whatever being given to a better production.

The continuous type of veneer jointer was developed for the furniture industry when double and triple dressers, etc., were not in design. A limit to the length of veneer to be jointed on this type of machine is considered to be 62 inches. A guillotine is therefore a must in the average plant today. A considerable number of continuous high-production splicers are available from Europe, but a single unit to handle both thick and thin veneers has not yet been designed. A guillotine, with a second cut, is a must when considering continuous cross-wide veneer splicing.

Moulders: Moulders with five and six heads have met with wide acceptance and have many advantages over a four-head machine. It is now possible to dress on the first two horizontal spindles and mould on the last two. This is an advantage in many operations. The wide use of straight and milled-to-pattern knives, in specially designed heads, are now cutting costs substantially, as well as assuring that patterns will match from run to run.

Future machines, in general, will run about twice as fast, some incorporating air holddowns, and likely have heavy horsepower on the spindles.

Band saws, shapers, jig saws and jointers: These machines, in general, have been improved and some provided with a series of feed speeds, for wider application. Safety features have also been incorporated, particularly on shapers.

Tenoners: The modern double-end tenoner is a woodworking shop in itself and, as such, deserves a full and detailed paper and discussion on its own. In addition to double tenoning, coping, tonguing and grooving, shaping, scarfing and dadoing, some European machines have incorporated boring units. Machines range from light to heavy duty, and there is a machine available in many price and production ranges.

Dovetailers: The latest machine to be developed is a double-end unit which, in addition to doing both ends, combines the boring for the drawer fronts and the branding of the name on the inside. These machines are fairly expensive and are warranted only in high production plants. The semi-automatic and fully automatic European machines would appear to meet more nearly our production requirements.

Boring and mortising: The introduction of hydraulic and air-operated boring machines, with multiple horizontal or vertical spindles has done much to cut down boring costs. A factor sometimes not taken into consideration, however, is that in multiple boring, with the machine properly set up, all pieces will be exactly the same, eliminating much loss time in assembly. The recent introduction into Canada of combination sawing and boring machines will cut costs at least 50 per cent on chair operations.

In addition, machines capable of boring from the rear, top, side and front are in production and, combined with automatic cut-offs on the same machine, offer tremendous production possibilities with resultant savings in costs. Multiple vertical mortisers,

either chisel, chain, or chain and chisel combinations are available. Air power, due to cushioning effect, is the most effective medium of stroke for these units. The wide use of air power in these operations is to be noted.

Sanding: The introduction since World War II of endless belt drum sanders, at reasonable prices, has brought the machines within range of the smaller manufacturer. Although new to both Canada and United States, these machines have had wide use and acceptance throughout the rest of the world. The advantages of a hydra-stroke, automatic belt sander, over block or pad sanding, is now accepted.

There is a wide variety of new sanders for curved or special jobs. In general, belt speeds have been increased and more thought and design incorporated into the machine, to make fuller and longer use of the sandpaper.

Turning lathes and dowel machines: New automatic turning lathes, built on the metal tracing principle, now eliminate the necessity to have a great mass and inventory of heads. This type of lathe incorporates a form to be followed, similar to the old back-knife gauge lathe. Dowel machines and dowel cut-off units have been made more efficient, automatic in many cases, and increased production-wise.

Assembly: Air-powered clamps are available for every known type of assembly work. By intelligent jigging these clamps offer speed, production, and lower costs. Air or electric screw drivers and automatic corner block machines are in fairly wide use. It is pointed out, however, that speed in assembly is the result of careful stock preparation by all other departments.

Finishing rooms: Conveyorized finishing rooms are becoming a must, incorporating the moving of the product from stage to stage, through the ovens, and into the shipping room. It must be pointed out, however, that although initial savings are easier to show in this department, it is entirely dependent on the kiln capacity to obtain these savings.

Cutting tools: The application of newly developed carbide-tipped tools throughout the woodworking industry has been nothing less than phenomenal, with tremendous savings in maintenance, down time, and retooling costs being realized by more and more furniture manufacturers. Among the machines to which carbide-tipped tools have been successfully adapted are moulders, variety saws, cut-off saws, tenoners, shapers, routers, and even jointers and planers.

Fig. 4.—Typical Industron panel-on-frame electronic press with hopper feed glue spreader is a high production unit.

Future: Foreseen for the future are: the development of more air-powered equipment; the development of more complex equipment, which for the furniture manufacturer, means cost and material savings (but better qualified maintenance men and maintenance are required); the wider use of conveyors, lifts, and combination machines; the introduction of humidity control in plants; and wider use of carbide cutting tools for all machines.

Considerations When Purchasing New or Replacing Equipment

(A) A priority system should be set up so that machines in daily use are replaced with more modern equipment, rather than replacing equipment which has only a limited use in the operation.

(B) A thorough study should be made of the operation being performed on the machine being considered, to see whether there is a better method of doing this operation or if perhaps it could be combined and incorporated on another machine which will do more than a single operation.

(C) Take the machinery dealer's representative into your confidence. Allow him to express his opinions and discuss thoroughly his equipment and what it will do for you.

(D) If it is the first machine of its type on the market, assure yourself that service and parts will be available. Most reputable dealers will have no hesitation in placing the machine in your plant under the above conditions.

(E) Purchase all of your woodworking machinery with an eye to expansion, so that you are not buying a piece of equipment which in six or eight months will have insufficient capacity.

(F) Make full use of the knowledge of your woodworking machinery sales representative who, through study, visits and discussions, is familiar with not only the problem you have but the problem in every plant within his territory. Your problem may have come up before with other furniture manufacturers and been solved.

(G) The last consideration should be price. It is as important to know what the machine will do for you as it is to know its cost.

(H) Purchase your equipment from reputable manufacturers or dealer organizations who are as interested in continuing to service the equipment as they are in the original sale. A firm financially strong will normally not close its doors a few months or a year after you have purchased a machine from them.

Conclusion

It is evident that machinery for the woodworking industry is keeping well ahead of demand as far as design is concerned. The slow response of the furniture manufacturers to change either procedure or method, regardless of merit, is partly the reason why the field is far behind in many respects.

Whereas equipment changes in two to five years are not uncommon in other fields and operators will allow machines to be practically developed in co-operation, these conditions appear to have no response in the furniture field. This condition has, to some extent, reflected back on the machinery manufacturer, who is not prepared to develop new equipment and methods which will take ten years to convince the furniture manufacturer that it is a better way of doing things.

First Minehunter Made of Laminated Preserved Timber Launched

THE FIRST SHIP to utilize preserved, pressure-treated laminated and solid timbers throughout the major portion of its construction was launched in March by the U. S. Navy. The ship, the U. S. S. Bittern, is also the first naval vessel to be originally designed and constructed as a coastal minehunter, all previous mine warfare vessels having been converted from existing ships.

Until the use of preservative pressure-treated red oak lumber was detailed in the Bittern's specifications, the Navy had used untreated white oak in the construction of most of its mine warfare vessels. Properly pressure-treated with preservative, red oak is more resistant to decay than untreated white oak and will greatly increase, if not double, the supply of ship and boat building grade oak for Navy use.

All preserved lumber in the ship was pressure-treated at the Orrville, Ohio and Nashua, N. H., plants of Koppers Co., Inc. Wolman salts were used for protection of timbers against decay fungi, except for a copper-bearing chemical used for marine borer defense in the sheathing of the underwater hull. Koppers' Penacolite resorcinol adhesive was used in all laminations of ship's timbers and for other gluing purposes. The structural glued laminated members used in the ship's construction were manufactured by Unit Structures, Inc., Peshtigo, Wis.

Conditioning after pressure treatment was limited to kiln-drying, using temperatures of less than 150° F. The moisture content of the lumber at the time of gluing could not be less than 10 nor more than 15 per cent. Moisture content of a core taken from any board could not vary more than 2 per cent from that of the shell of the board.

View from inside pressure-treating cylinder showing tram car loaded with untreated lumber headed for the cylinder and pressure treatment with Wolman salts for use in construction of U. S. S. Bittern.

Laminated, pressure-treated ribs for the Navy minehunter loaded aboard a special railway car for shipping to Consolidated Shipbuilding Corp., New York.

Edge-joining and end-joining permitted full width and full length laminations when pressure-treated, to provide a suitable alternate for solid members, especially for those of considerable length or of moderately large cross-section.

For laminating, the resorcinol adhesive was spread not less than 30 pounds per 1,000 square feet of surface on each face of each lamination. Careful temperature control in all phases of the gluing procedure assured a laminated member meeting or exceeding the tests specified. The average block shear strength of all glue lines exceeded 1,800 psi.

Bent members could be laid up in either male or female form and were drawn snug before applying pressure. Assembly pressure of plus or minus 175 psi was required and rechecked 30 to 45 minutes after application.

Preservative-treated and kiln-dried lumber was end cut by special scarfing machinery at the Peshtigo plant and end-joined to produce laminations of the required length. After surfacing, the laminations were coated with adhesive and assembled against a forming jig. Screw clamps operated by impulse wrenches pulled the laminations into place and applied a uniform pressure of 150 to 200 psi to all glue lines.

The curing process was broken into three stages: heating, curing, and cooling. After being brought up to a curing temperature, heat was held at a minimum of 150° F. at the glue line for a specified period of at least ten hours. Then the member was cooled to a point where humidity control was no longer required and it could be removed from the jig. Frames or ribs of the vessel were surfaced two sides, patterned, and then beveled to receive planking during construction at the shipyard.

The Bittern looks much like any of the coastal minesweepers now in service, having about the same length, 138 ft., a beam of 27 ft. and a full load displacement of 360 tons. More than 7,000 pounds of adhesive was used in laminating about 70,000 bd. ft. of timbers.

Every effort was made to keep the ship as non-magnetic as possible to counter the advances in magnetic and acoustic mines. Even the huge, walk-in refrigerator was made of preserved pressure-treated plywood. In places where wood could not substitute for metal, non-magnetic bronze, aluminum or stainless steel was used.

The ship, named in honor of a minesweeper of the same name which was lost at Cavite in 1941, was built by Consolidated Shipbuilding Corp. of New York under contract to the Navy's Bureau of Ships. Sparkman & Stephens, New York City, were designers of the ship.

Ready on the ways, the U. S. S. Bittern is shown awaiting the launching ceremony.

Around the World in Forest Products Research and Development

French Center Studies Sawing Efficiency

wing with the circular saw is the subject of extensive studies being carried out at the Centre Technique du Bois, Paris, France. Experiments have been made on thin and extra thin saws to determine use limits and with circular saws small set and having a small number of teeth.

The experimental sawmill is equipped with 100 cm. band saw having special improvements, including an individual sulky drive and a gearbox for the carriage feed mechanism to give a range of eight cutting speeds from 11 to 55 m/min. The carriage can be operated either manually or automatically and is also fitted with a rapid feed to give a maximum speed of 60 m/min.

Special handling equipment includes a capstan, roller conveyor, and carrylift. Instruments for measuring power consumption are worked by remote control and record the power absorbed by various machines.

Tooth designs have been specially studied and two types were found to give excellent results in the sawing of softwoods. The first was patterned on the "Duo Kerf" design of L. H. Reineke of the U. S. Forest Products Lab, Madison, Wis. It allows a freer extraction of sawdust, gives a better sawn surface, and also results in a reduction of power consumed at certain speeds.

The second type, Perroquet tooth design, was devised to ensure better blade efficiency and improve sawdust extraction. This is an improved gullet tooth in which all the straight parts have been changed to curved. Two versions were designed for sawing hardwoods and softwoods.

A special feature of the Perroquet tooth design is that the angle of cutting edge may vary between 22 and 30 degrees. The harder the wood the smaller should be the angle as the pressure of the wood on the blade would become too great, causing the blade to move backwards on the pulleys. The clearance angle should be from 8 to 10 degrees.

—FAO Equipment Note D. 6. 55

Scanning World-Wide Forest Products Publications

Australia

A Precision Frame Gang Saw Built in a Sawmill. Part II. D. S. Jones, C.S.I.R.O. Forest Products Newsletter, No. 220.

Logs are fed into the machine (see page 33-A, March JOURNAL) using two rail-mounted trolleys. The tail trolley has air-operated dogs to grasp the end of the log and hold it firmly while it advances over the planer and towards the saw. Logs are transferred from the log haul chain onto the two trolleys by an air operated winch, also used to rotate logs into the best cutting position.

As the front of the log approaches the saw blades, the front top feeder roller is lowered and pressure applied. As soon as the front of the log is far enough out of the saw, pressure is also applied to the log with the back top feed roller. Logs are sawn with the wide end first so that short waste side slabs can be removed early in the cutting cycle.

When the front of the log emerges from the machine, the pieces are chained together. Behind the saw the log is first supported on cross-rails moving on a chain; about 10 feet from the saw is a pair of vertical rollers that pneumatically press the sawn pieces together and give added lateral support during the latter part of the cut. When the end of the log leaves the back feed rollers, the vertical rollers are released and the sawn log, held together by the chain at the front end, moves forward away from the machine, first on the moving cross-rails, then on powered rollers.

The sawmill in which this machine operates is producing 250–280,000 super feet of sawn timber per month, and attains an average recovery of 59 per cent based on true log volume.

Japan

Water Repellency, Water Absorption and Moisture Adsorption of Wood Treated with Synthetic Organosilicone Compounds. Y. Yamagishi, Journal of Japan Wood Research Society, Vol. 2, No. 1.

In this experiment, water repellency of wood treated with organosilicone compounds has been studied. For the purpose of giving water repellency to wood, two methods were chosen: overcoating by organosiloxane (T) and organosilane (K) in ligroine, and treating with organohalogenosilane in vapor state.

As it was difficult to measure directly the angle of contact between the treated wood and water, quality of water repellency of the treated wood has been evaluated by the angle of incline when the drops of water on the surface of wood start to flow. From two to seven drops of water were dropped from a constant height (four cm. high from the wood surface) by a burret. The concentrations of organosilicones (T,K) were 10, 5, and 1 per cent.

The following results were recognized: it is possible to evaluate water repellency by the angle of incline when the water drops start to flow, to give water repellency to wood consequently diminishes the water absorption, and in moisture adsorption there is no change.

Other Developments Around the World

Yugoslavia

• Yugoslavia has gained reputation on the world market for her exports of hardwood lumber, particularly sawn oak and beech timber, known as Slavonian oak and Slavonian beech. Slavonian in both cases is used as a description for a certain quality and does not refer to geographic origin. Most important in trade are the summer oak *(Quercus pedunculata)* and the winter or sessile oak *(Quercus sessiliflora* Salisb.)

Beech is the most widespread tree species and can be found in nearly all parts of the country, although the best comes from the mountainous regions. Once used mainly for firewood, today beech is manufactured into a whole series of marketable goods. There is a particular demand for steamed sawn beech timber and rotary cut veneers. It is used in the building industry, mines, and in barrel and furniture manufacture.

Ash is used especially for furniture, parquets, carts, and railway cars. It is further used in construction of machines, mostly for the textile industry, but also in agriculture and sports articles.

—Yugoslav Timber Industry, 1945–1955.

Abstracts From Current World Literature

Finishing

N. J. Gaynes. Problems with infra-red. *Industrial Finishing,* U. S. A., Vol. 32, No. 5. March 1956.

Difficulties encountered with the new infra-red baking ovens are mostly caused by an incomplete understanding of the theory involved. As is generally known sunlight or white light, when refracted through a prism, will be broken down as a rainbow into its component colors of the spectrum. These colors are easily seen by the human eye, but there are other colors which are not visible. These are ultra-violet, which is in the short wavelength area beyond the visible violet, and infra-red in the wavelength area beyond visible red. The infra-red ray is able to penetrate and be absorbed into materials where the light energy is transformed into heat energy-giving radiant heat.

In convection type baking of paints, for example, the outer surface is baked more rapidly than the inner surface, whereas infra-red, which does not depend on conducted heat, penetrates immediately giving simultaneous heating on inner and outer surfaces. As, however, light beams travel only in straight lines, such baking is impractical if the product being finished has portions shielded from direct or reflected rays.

These installations are especially suitable for automatic production lines, but as infra-red is derived from electrical power the relatively high cost may prove uneconomical. [F. D. C. Tech. Bul. V. 6, No. 32]

How to overcome sanding problems. *Furniture Record,* Vol. 148, No. 296, 15 June 1956.

The most common sanding irregularities are chatter and snake marks. These can be caused by vibration in the sander due to worn bearings, poor felt backing, excessive pressure on the wood, or foreign materials on the felt or abrasive. In many plants excessive pressure is judged by ear only but ammeters can be mounted on each drum for checking the energy absorbed.

Drum speed is important both in preserving the life of the abrasive and in giving the required finish. Tests indicate that optimum speeds for drums 24 and 36 in. in circumference run from 3450 to 3750 and 5100 and 5400 surface feet per minute. It was found that slower speeds on the cutting drums allowed greater abrasive efficiency for initial cutting, and faster speeds on polishing drums give a finer finish and reduce sanding time on subsequent operations.

For white wood flat stock, stroke sanding blends and removes scratch patterns left by the drum sander. A light touch in this operation allows the abrasive to cut the wood fibres rather than press them down.

For edge sanding garnet and aluminum oxide cloth are the most common of several types of abrasives used, with operational speeds of between 3000 and 4000 sfpm.

Burning by heat transfer from the platen is a problem, but this can be guarded against by using an aluminum oxide cloth belt with resin bonding or a sander pad cover and graphite on the platen. [F. D. C. Tech. Bul. V. 6, No. 32]

Veneer and Plywood

Anon. Major advance in plywood product technology. Paper Ind. 37, No. 12: 1110–11 (March, 1956).

A weather- and waterproof, plastic-surfaced fir plywood panel called Duraply permits the utilization of veneer from lower-cost raw material such as second-growth timber and sawlogs. Crezon, a resin-impregnated cellulose fiber developed by Crown Zellerbach Corp., is permanently fused to the wood under heat and pressure. A patching machine fills all defects in the wood with a special compound. [Bul. Pap. Chem. V. 26, No. 8]

Residue Utilization

Jenkins, J. H. Progress in the utilization of sawmill waste for pulpwood. Pulp Paper Mag. Can. 57, No. 5: 136–8 (April, 1956).

The utilization of sawmill waste in British Columbia, some developments in the United States, progress in Eastern Canada, and future developments are covered in this review of progress in the past 10 years in the utilization of waste wood for pulpwood. The accomplishments of a research committee formed in 1951 to study the problem are summarized. [Bul. Pap. Chem. V. 26, No. 10]

Cone, C. D., Jr. A brief survey of bark utilization. Southern Pulp Paper Mfr. 19, No. 4: 92–4 (April, 1956).

Two primary ways in which the problems confronting profitable bark utilization could be solved are the development of simple, inexpensive, and easily produced bark products which require only a relatively small capital investment in plant and equipment, or the erection, in an area where pulp and/or sawmills are concentrated, of a relatively large plant capable of breaking down the bark into a large number of marketable products. Some of the research being carried out at the Herty Foundation on the chemical, physical, and physicochemical properties of pine bark is described. [Bul. Pap. Chem. V. 26, No. 12]

Packaging

Hoover, William J. Toppling warehouse stacks point up urgent need for better cartoning. Food Eng. 28, No. 6: 56–9, 87 (June, 1956).

The most important cartoning problem is lack of stacking strength in shipping cartons. Increased use of mechanical palletized handling and higher piling heights necessitates the development of stronger fiberboard containers. Elements contributing to stacking strength are container size and shape; glues, tapes, and adhesive; and structural design. The effects of handling, actual load on the box, storage temperature and R.H., length of storage period, and stacking or pallet pattern used are discussed. [Bul. Pap. Chem. V. 26, No. 11]

Properties

Handbook of hardwoods. Forest Products Research Laboratory, H. M. Stationery Office 1956, 269 pp.

The book replaces the two earlier issues, 'A Handbook of Empire Timbers' and 'A Handbook of Home-grown Timbers' as it has been decided that it is more useful to group hardwoods and softwoods in separate volumes and bring together the home-grown and imported timbers in each class. It contains up-to-date information on hardwood species already dealt with, as well as a number of additional species, many of them comparatively new to the U.K. market. Altogether full descriptions are given of 151 timbers and brief mention made of another 64.

For each timber the botanical, ordinary and any other names are given, a general description of the tree and the timber, seasoning mechanical and bending properties, resistance to insect attack, natural durability, preservative treatment, working properties, use in veneers and plywood, and other uses. [F.D.C. Tech. Bul. V. 6, No. 32]

Preservation

Spray treatment for prevention of *Lyctus* attack in sawn logs. F.P.R.L. Leaflet No. 43, February 1956.

Spray treatment of timber against *Lyctus* is recommended only as a preventative and is of little value for timber which has already been attacked or is exposed to infestation.

Recommended sprays are emulsions in water, which can be made up from commercially available miscible oil concentrates, and will not discolor or in any way affect the working properties of the timber. A slight greyish deposit may be left if a formulation of suspended water dispersible dusts is used.

Spraying should be done as soon as possible after the beginning of March before the emergence of the beetle. Respraying would be necessary for continued protection after resawing of the boards. [F.D.C. Tech. Bul. V. 6, No. 32]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

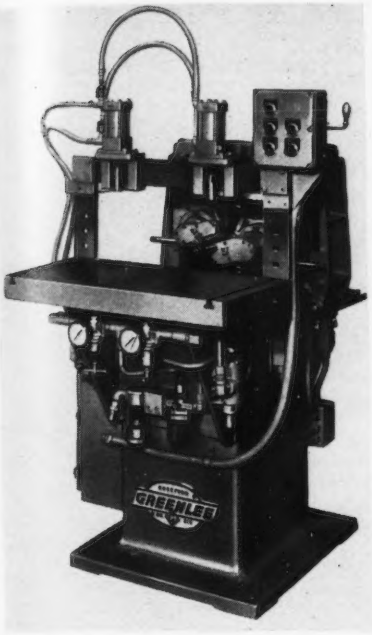
TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

NEW PRODUCTS—LITERATURE

Horizontal Dowel Borer

A dowel boring machine which will reportedly permit rail and end-boring operations to keep pace with production in many types of wood-product manufacturing has been designed by Greenlee Bros. & Co., Rockford, Ill.

The new two-spindle, horizontal dowel borer features pneumatic feed and clamping. A pneumatic cylinder,



mounted under the table, provides constant feed stroke for the spindle carriage and work is held in position by an adjustable pneumatic-clamping arrangement.

The spindles are located on a 4-inch radius from the center of each motor arbor and are radially adjustable through a worm-gear crank. This permits a center distance adjustment from a 1-inch minimum to a 16-inch maximum in the horizontal plane. A vertical adjustment of 8 inches is provided through a screw arrangement with a crank-square located at the top of each side-support casting.

Moisture Measuring System

Moisture content of lumber can be measured while the stock is in the dry kiln and without a kiln shutdown by means of an electrical system developed by Delmhorst Instrument Co., Boonton, N. J.

The "Kil-Mo-Trol" consists of a standard Delmhorst Moisture Detector and a "Station Selector" located at the kiln control board. Outlets and cables, connected to the station selector, are installed along the kiln walls. Contact pins are driven into the lumber where measurements are desired during the drying operation, and these pins are

then connected to the wall outlets with load cables. The Delmhorst Detector is then connected to the station selector so that by turning a switch the kiln operator can make shell and core tests of lumber anywhere in the kiln charge where contact pins have been located.

The system shows when lumber dries fast or slow and indicates such faults as excessive or inadequate radiation, clogged traps, faulty baffling, and burned out motors. It also eliminates the cost of sample boards and permits tests to be made in all parts of the kiln.

Automatic Edger Setworks

A pre-determining, remote control edger shifter setworks has been designed by Heaps Machinery, Ltd., P. O. Box 10, 400 Ewen Ave., New Westminster, B. C. The electronic device reportedly sets fast and accurately and does not creep when required for continuous operation at the same setting over a long period of time.

The edger setworks has a setting speed of approximately 30 feet per minute to plus or minus .01 inch accuracy. Other advantages reported by the manufacturer are: full realization of the cant; accurate sized lumber, which results in lower shipping charges when shipped rough and greater chip recovery; and several safety features.

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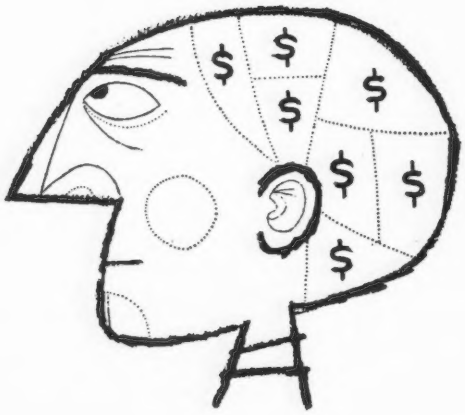

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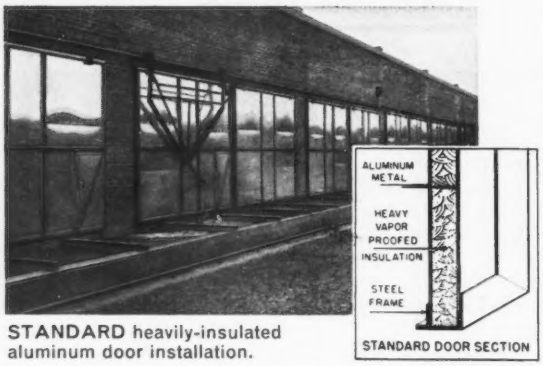

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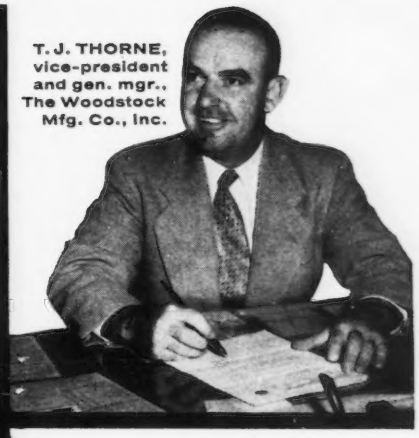
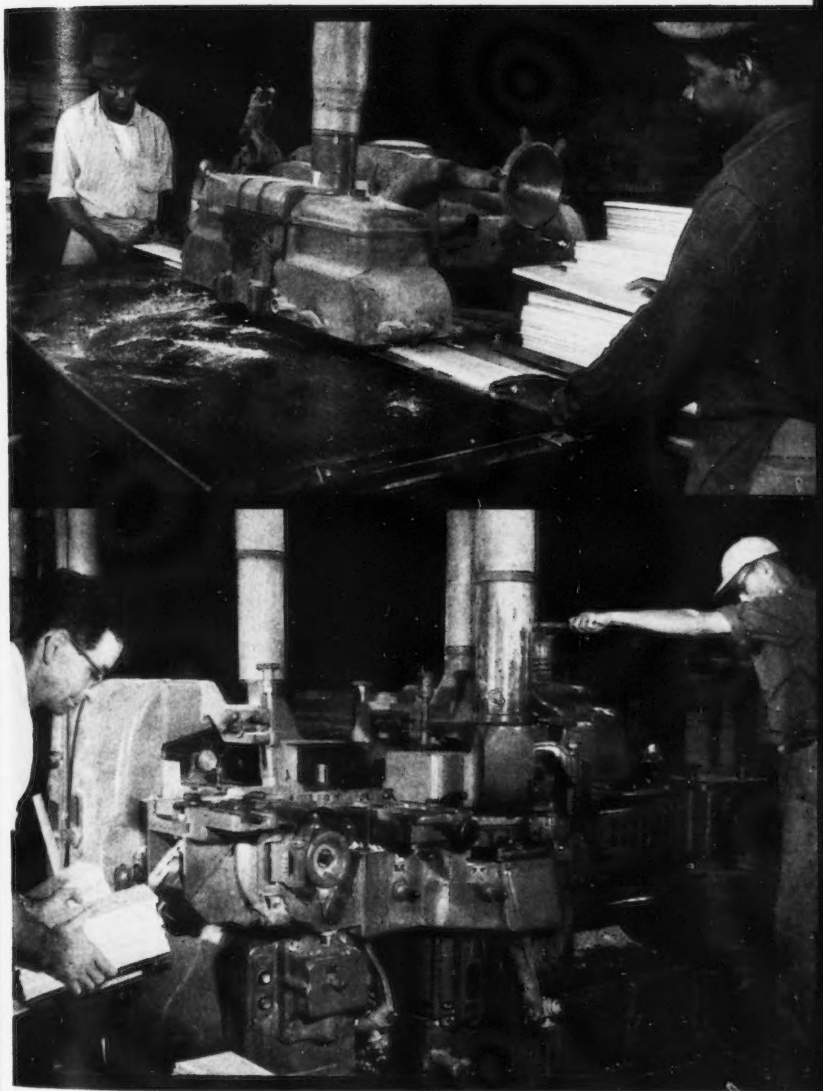


T. J. THORNE, vice-president and gen. mgr., The Woodstock Mfg. Co., Inc.



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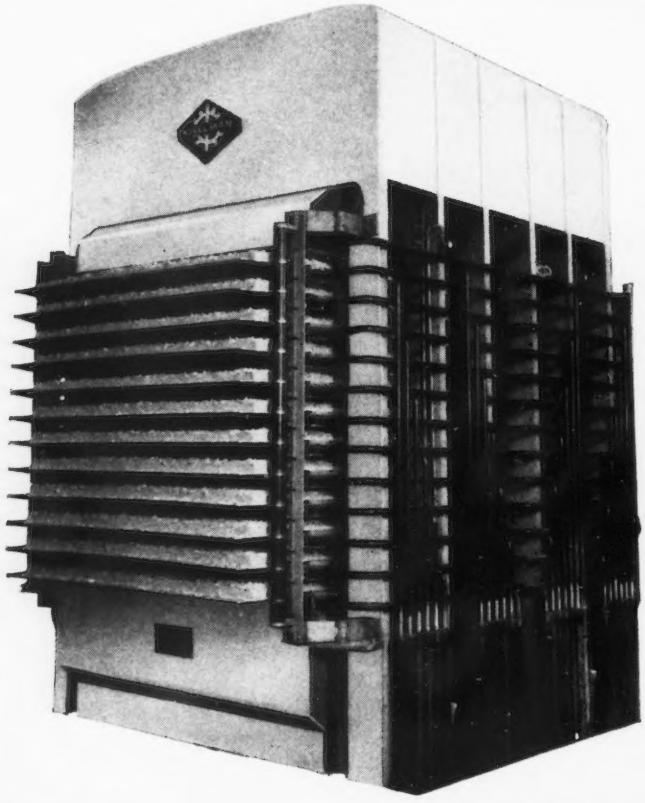

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